Microprocessors and the Digital Revolution

Security, Quality, Reliability, and Availability (SQRA) in the Digital Age

Final Draft Report, May 2002

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REPORT SUMMARY

This report provides insights on the role and significance in modern society of digital technologies, applications of digital technologies, and the digitally enabled enterprises that have sprung from them. Special emphasis is given to the need for Security, Quality, Reliability, and Availability (SQRA) of the interface between electric power delivery and digital systems, digital processes, and digitally-enable enterprises.

Background
The digital revolution rides on the back of new digital technologies that have broadly influenced improved energy efficiency, productivity, communications, automation, and other benefits. These technologies, while opening whole new horizons of commerce and innovation, also have exposed vulnerabilities in the traditional technologies and methods used to interface electric power delivery with digital systems, processes, and enterprises.

Objective
To develop a framework for understanding the broad impact of digital systems, processes, and enterprises on our society and to lay the groundwork for understanding the importance of optimally interfacing electric power delivery with the digital economy. Optimizing this interface will require a strategy that must comprise all elements of the power delivery and end-use process—from the power plant, to the interconnecting systems, to the response of the digital systems, processes, and enterprises themselves—and will be met with a combination of implementation techniques, new technologies, and new approaches to interfacing electricity supply with all forms of digital applications.

Approach
Issues considered in this report include a comprehensive analysis of defining what is meant by “digital” particularly in the context of interface with electrical energy delivery, and qualifying and quantifying the role that digital technologies play in modern society.

Results
The impact of digital technologies on modern society is profound and growing, with broad influence on economic growth, energy efficiency, and productivity. Approximately 12% of U.S. electric energy in 2001 was delivered to digital devices, by enterprises making them, or by elements of modern society that would not exist except for digital technologies. Digital energy use will grow to 16% of the U.S. total by 2011.

There is a clear economic and national security imperative for the U.S. to understand the role that new digital technologies play in modern society, and to understand the Security, Quality, Reliability, and Availability (SQRA) needs of these important technologies. Specific capabilities are needed for electricity to meet the needs of the digital society:

- **Security:** The digital society is extremely productive and capable, but also vulnerable. The interface between digital systems, processes, and enterprises and electric power delivery is a principal vulnerability, but one that can be hardened against attack.
- **Availability and Reliability**: The digital society is expected (and designed) to be continuously operational, without interruption or denial of service. The interface between digital systems, processes, and enterprises and electric power delivery must support this availability, with innovations spanning from the generation sources to the microchip.
- **Self-healing and Redundant**: Digital communications use a network of high-capacity nodes to route data efficiently and expeditiously. The interface between digital systems, processes, and enterprises and electric power delivery needs the same capability.
- **Massive customization**: The digital revolution has revealed an inexhaustible appetite for instant and user-specific customization of service and support. The interface between digital systems, processes, and enterprises and electric power delivery must have this capability to support this revolution.
- **Rapid reconfiguration**: The digital world has demonstrated its ability to rapidly adjust to changing requirements. For example, the Internet evolved from a simple document exchange system just a few years ago to the now familiar capabilities of email, online transactions, and data presentation. Even newer technologies are now being implemented, such as video conferencing, voice-over-IP, and civic systems such as Web-based voting. The interface between digital systems, processes, and enterprises and electric power delivery must be able to emulate this rapid adaptive behavior to support the digital society.

These capabilities include components of the traditional power delivery infrastructure, the need for enhancement to those capabilities, and the need for increased availability of DR.

EPRI Perspective

A technology revolution is sweeping modern society, abetting the beginning of a new era of economics and social revolution driven by microprocessors and the digitally based technologies that they enable. As a result, our society has become the most highly automated and interconnected in history—creating, and dependent on, the smooth functioning of sophisticated devices and complex, interactive networks.

Digital technologies have a broad influence on modern societies. The basic digital building blocks enable a wide range of applications, greatly influencing the residential, commercial, and industrial sectors. In turn, these capabilities support whole digitally enabled enterprises whose modern form is entirely based on digital technologies.

Keywords

Security
Power Quality
Reliability
Availability
Digital Technologies
Digital Society

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INTRODUCTION

Through a unique collaboration of public, private, and government stakeholders, EPRI's Consortium for Electrical Infrastructure to Support a Digital Society (CEIDS) provides the science and technology to ensure an adequate supply of high-quality, reliable electricity to a digital economy and to integrate energy users and markets. This mission is realized in the meeting of three critical CEIDS goals:

- Lead in anticipating and meeting tomorrow's electric energy needs
- Enhance value for all CEIDS partners
- Create and foster opportunities to enable a digital-quality power supply

This report provides insights on the role and significance in modern society of digital technologies, applications of digital technologies, and the digitally enabled enterprises that have sprung from them. Special emphasis is given to the need for Security, Quality, Reliability, and Availability (SQRA) of electricity in fueling the digital revolution.

The Digital Revolution

A technology revolution is sweeping modern society, abetting the beginning of a new era of economic and social change driven by microprocessors and the digitally based technologies that they enable. As a result, our society has become the most highly automated and interconnected in history—creating, and dependent on, the smooth functioning of sophisticated devices and complex, interactive networks. And this revolution has just begun.

Digital technologies have a broad influence on modern society. The basic digital building blocks facilitate a wide range of applications, greatly influencing the residential, commercial, and industrial sectors. In turn, these capabilities support whole enterprises whose modern form is entirely based on digital technologies (see Figure 1-1).

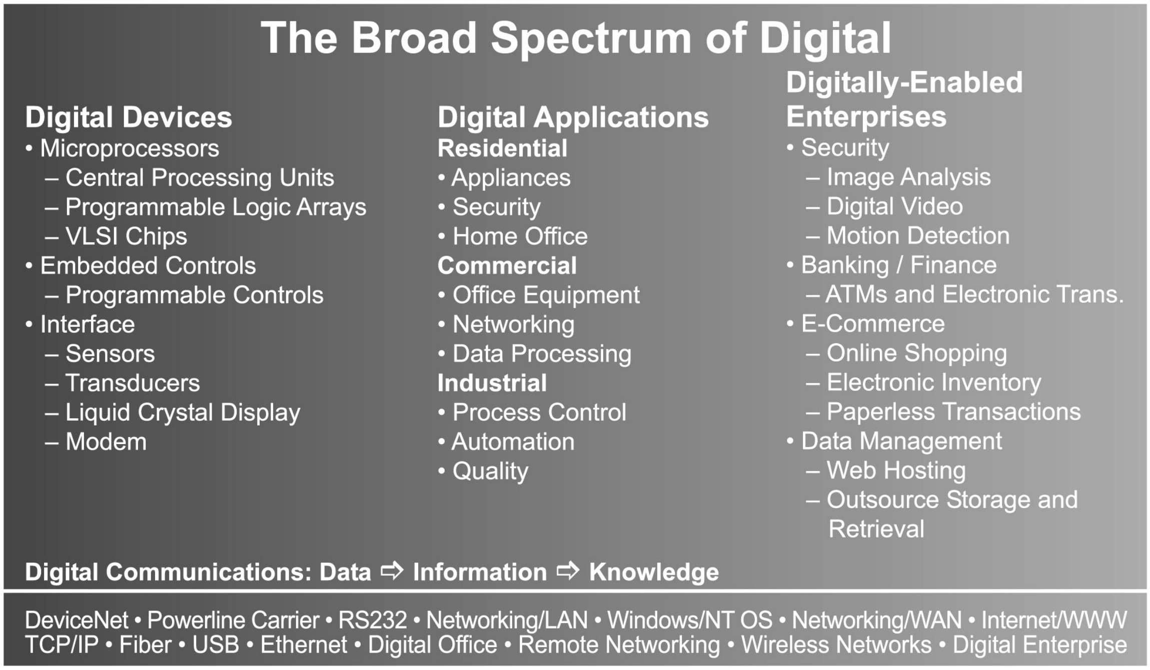

Figure 1-1
The Broad Spectrum of Digital Systems, Processes, and Enterprises

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Our society has become the most highly automated and interconnected in history—creating, and dependent on, the smooth functioning of sophisticated devices and complex, interactive networks.

The digital revolution rides on the back of new digital technologies. These technologies, while opening whole new horizons of commerce and innovation, also have added vulnerabilities to power supply issues. Imagine that one lightning strike or power supply fault anywhere within a few hundred miles interrupts a company’s processes, causing thousands of dollars in lost production and labor, equipment damage, and creation of scrap. Or imagine you’re a utility engineer responsible for power quality and reliability and, despite earnest efforts to quickly dampen or isolate the effects of that single lightning strike or isolated fault on a remote power grid, the entire distribution system sags—affecting hundreds, if not thousands, of digital systems, processes, and enterprises.

These unsettling scenarios are reality for virtually every major interconnected power grid in the world. Transmission-level problems can cause voltage disturbances—mostly sags, in which voltage on one, two, or all three phases drops below normal levels for a brief period—in distribution systems over a wide region. For example, a computer model-based study of transmission and distribution systems in the Albuquerque, New Mexico, area found that sensitive electronics there were vulnerable to transmission system faults occurring anywhere in the entire state, not just on local supply lines.[1] A study of electric supply vulnerability for a paper mill near

[1] Narain G. Hingorani, “Introducing Custom Power,” *IEEE Spectrum* (June 1995), pp. 41–48.

Manchester, U.K., found that the facility faced 56 significant transmission and distribution related sags per year. Of these, 89% were caused by incidents on long 400-kilovolt transmission lines spanning many kilometers.[2]

There are clear economic and national security imperatives for the U.S. to understand the role that new digital technologies play in modern society, and to understand the Security, Quality, Reliability, and Availability (SQRA) needs of these important technologies, particularly in the area of electric power supply. Specific capabilities are needed for electric power delivery to meet the needs of the digital society:

- **Security:** The digital society is extremely productive and capable, but also vulnerable. The interface between digital systems, processes, and enterprises and electric power delivery is a principal vulnerability, but one that can be hardened against attack.
- **Availability and Reliability**: The digital society is expected (and designed) to be continuously operational, without interruption or denial of service. The interface between digital systems, processes, and enterprises and electric power delivery must support this availability.
- **Self-healing and Redundant**: Digital communications use a network of high-capacity nodes to route data efficiently and expeditiously. The interface between digital systems, processes, and enterprises and electric power delivery needs the same capability.
- **Massive customization**: The digital revolution has revealed an inexhaustible appetite for instant and user-specific customization of service and support. The interface between digital systems, processes, and enterprises and electric power delivery must have this capability to support this revolution.
- **Rapid reconfiguration**: The digital world has demonstrated its ability to rapidly adjust to changing requirements. For example, the Internet evolved from a simple document exchange system just a few years ago to the now familiar capabilities of email, online transactions, and data presentation. Even newer technologies are now being implemented, such as video conferencing, voice-over-IP, and civic systems such as Web-based voting. The interface between digital systems, processes, and enterprises and electric power delivery must be able to emulate this rapid adaptive behavior to support the digital society.

Understanding SQRA

Ensuring the continued vibrancy of the Digital Revolution requires careful attention to ensuring its Security, Quality, Reliability, and Availability, particularly in the area of the interface between electric power supply and digital systems, digital processes, and digitally-enable enterprises, and focusing on SQRA all the way from the generation of electric power to the connecting pins on semiconductor chips. Taking a closer look, we'll start with Reliability:

Reliability

Reliability, the starting point for building increasingly available systems, is a function of the design, component selection, and manufacturing processes. It is possible to define reliability as

[2] Math H.J. Bollen, Thavatchai Tayjasanant, and Gulali Yalcinkay, "Assessment of the Number of Voltage Sags Experienced by a Large Industrial Customer," *IEEE Transactions on Industry Applications*, v. 33, no. 6 (November/December 1997), pp. 1465–1471.

anything that serves to reduce the probability that a failure will occur (thereby increasing the system's availability), and which serves to maintain data integrity, thus reducing the probability that the system is inoperable or that bad data or results will flow through it undetected. Applied to electric power supply, Reliability is usually calculated as the total percent of time voltage is present, and usually stated as the number of "nines" of reliability. For example, a power system that is down for 60 cumulative minutes each year would be said to be 99.98% reliable, or "three nines." Electric supply to sophisticated digital systems is generally considered to require reliability of "six nines" or better, meaning less than 32 seconds of electric power outage allowed per year. Achieving this level of performance requires significant augmentation with new technologies and techniques. However, today's options are often costly and require added maintenance.

Availability

Reliability and Availability are closely related in that each is a measure of time (or percentage of time) that a process is up and running. Availability, however, acknowledges that once a process is interrupted, time is usually required to effect repairs and get things up and running again. Availability for sensitive digital processes acknowledges that there is a difference over the course of a year between a single one-hour electric power interruption and sixty one-minute interruptions. Since both these scenarios have 60 minutes of cumulative outage, the calculation of Reliability in both cases would be the same. However, the calculation of Availability would take into account the restart time of the process. For example, if 30 minutes were required to restart a sensitive digital process after an electric power interruption, Availability of the digital process in the case of a single one-hour outage per year would be 99.98%. However, Availability of the process drops to 99.64% (over 31 lost hours per year) when subjected to 60 one-minute outages and restarts per year. Again, achieving availability levels above 99.98% typically requires significant augmentation with new technologies and techniques, and today's options are often costly and require added maintenance. New, innovative solutions, comprising the whole of the power delivery and end-use process, are needed. Various levels of Availability used in the data-handling industry are shown in Table 1-1.

Table 1-1
Levels of Availability (Source: Sun Microsystems)

System Type	Unavailability (Minutes/Year)	Availability (Percent)	Availability Class
Unmanaged	50,000	90	1
Managed	5,000	99	2
Well-Managed	500	99.9	3
Fault Tolerant	50	99.99	4
Highly Available	5	99.999	5
Very Highly Available	0.5	99.9999	6
Ultra Highly Available	0.05	99.99999	7

Quality

Just as Availability takes Reliability one step further, so with Quality—a measure of the quality of power delivered to digital systems. While both Reliability and Availability tend to focus on complete interruptions of power, power Quality acknowledges that there are other characteristics of electric power supply that can impact the performance of sensitive digital systems. Examples of these include sags, spikes, or transients in supply voltage as well as unbalanced voltages, poor electrical system grounding, and harmonics. Quality is influenced not just by power delivery systems, but also by end-user equipment and facilities.

Security

Taken collectively, the interface between electric power supplies and the sophisticated digital processes they serve can perhaps best be characterized as being primarily about Security. How safe, appropriate, and trustworthy are electric power supplies? Can they be relied upon to perform in a robust, resilient, and self-healing way to cope with the many challenges—both natural and human-made—that can confront any important societal infrastructure? The answer to this lies in our ability to make this interface as intelligent, automated, and self-diagnosing/ repairing as possible, and thereby make the digital economy as Reliable, Available, and high-Quality as possible. Supplies to critical facilities or applications can be made more secure though innovation in broadband communications and self-healing technologies.

The Microprocessor Revolution

It is difficult to assess the true impact that microprocessors have had on our society, economy, and way of life. The sheer number of these devices already in existence and regularly entering society is already staggering, and all aspects of modern economies are affected (see Figure 1-2). Although computers are the most obvious application of microprocessors and other semiconductor chips, these comprise less than half of the applications. Consumer electronics and communications collectively use a third of semiconductor output. A large number, 10%, goes to improving the productivity of industry.

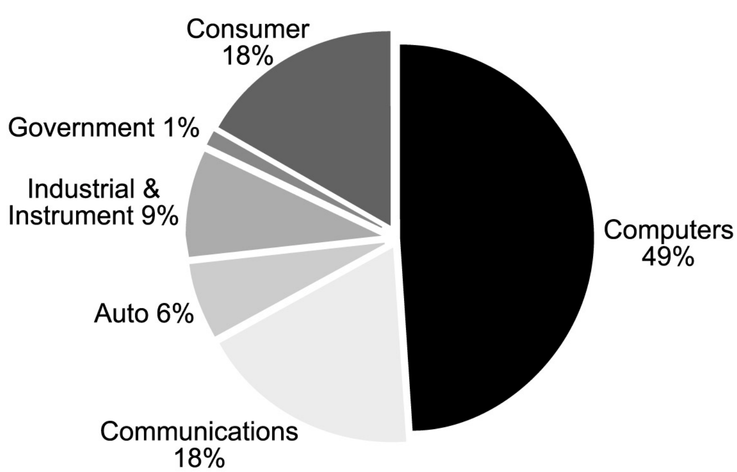

Figure 1-2
Application of Semiconductors: Percentage by End-use Sector (Source: Semiconductor Industry Association)

The microprocessor revolution has enabled a host of innovative opportunities to improve energy efficiency, productivity, communications, and quality of manufactured goods.

With every revolution, there is a rapidly moving "cutting edge" that sweeps through society with astonishing speed, leaving some chaos in its wake. The years following these revolutions can be characterized as times of re-stabilization and catching up—a time when the rest of society adjusts and compensates for the changes that have unfolded. True to form, the microprocessor revolution has strained communications resources, pushed the envelope of privacy, exposed flaws in previous security practices, created an inexhaustible appetite for communications bandwidth, challenged censorship and content strictures, and spawned entirely new kinds of businesses, including co-location facilities and "mortar-less" marketplaces. The microprocessor revolution has also enabled a host of innovative opportunities to improve energy efficiency, productivity, communications, and the quality of manufactured goods (see Figure 1-3). The revolutionary aspects of microprocessors offer both enhancements as well as challenges to the economy and standard of life. Although much has been made of the amount of energy microprocessors use, this same technology can offer energy savings opportunities that are far greater. While it is also true that microprocessors and the digital devices they enable can demand much higher performance from electrical supply systems, they also enable significant improvements in productivity.

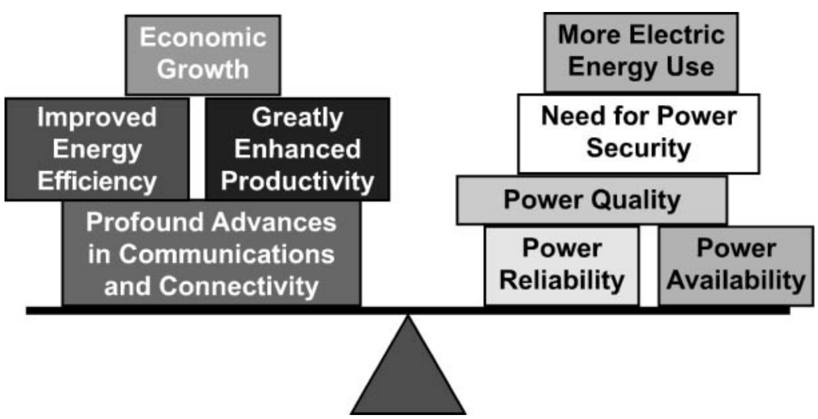

Figure 1-3
Balancing the Benefits and Costs of Microprocessor Technology

Other technology revolutions—electric power, telephone communications, rail transport, and automobiles to name but a few—have previously transformed whole societies, and the digital revolution is clearly no exception. There is an emerging digital society that has crossed over into a new era of economics and social experience, driven by digitally based technological changes that are producing new ways of working, new means and manners of communicating, new goods and services, and new forms of community. And, not surprisingly, this digital revolution is also fostering a new set of compelling challenges.

The economic growth fueled by the digital revolution is already the stuff of legend. According to U.S. Department of Commerce data, while the U.S. gross domestic product (GDP) grew an average of 4.32% per year between 1996 and 2000[3], one element of the digital economy, Internet-based business, grew by a staggering 174.5%, creating some 1.2 million new jobs.

While the industrial revolution was powered primarily by steam, the digital revolution is all electric—perhaps the first substantial industry to be so. Much of the world's electrical infrastructure was designed and built in the 1930s and 1940s in an era that primarily focused on "electrification," the simple goal of making electric power available to most people and most businesses, most of the time. The electrical system is now caught in the post-revolutionary challenge of catching up to the new demands placed upon it by a 24/7 digital world. To succeed, the strategies for powering the digital economy must undergo a revolution no less profound than that occurring in the digital technologies.

While the industrial revolution was powered primarily by steam, the digital revolution is all electric—perhaps the first substantial industry to be so.

But before optimum solutions can be evaluated or even new technology needs identified, we must clearly know with what we are dealing, which requires a better understanding of the impact of microprocessors and of the power and energy requirements for the digital technologies that they enable. This report seeks to satisfy the inherent need to better understand the power and energy characterisitics of digital technologies by focusing on three main issues:

- Finding a practical and working definition of "digital technologies."
- Establishing a framework and methodology for inventorying, tracking, and forecasting digital technologies.
- Identifying past and present trends in electrical usage of end-use digital equipment and characterizing their impact on the economy.

The Role of Semiconductors in Improving Energy Efficiency and Productivity

Although much has been made of the amount of energy microprocessors use, less discussed are the profound positive impacts that improved, digitally based controls can have on energy efficiency and productivity. While a number of studies have attempted to show that digital technology is fueling a surge in electric-power demand, these studies, because of their limited scope, often miss the tremendous benefits to energy efficiency and productivity that these same technologies have enabled (see Figure 1-4). Electrification of the U.S. economy has yielded profound benefits to overall energy efficiency and productivity.

[3] 2000 GDP statistics from U.S. Department of Commerce Bureau of Economic Analysis, http://www.bea.doc.gov/.

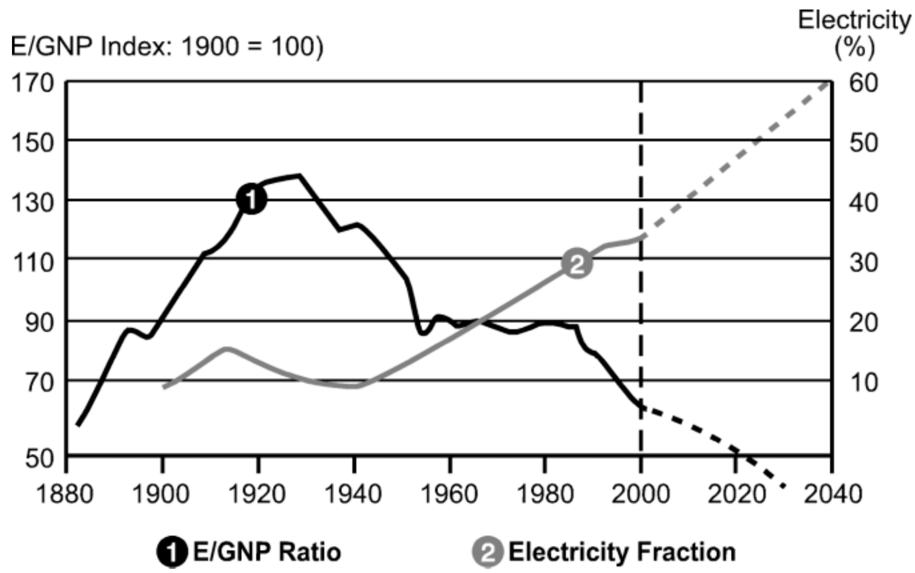

Figure 1-4
Improved Efficiency with Electric Power (Energy expense vs. Gross National Product, E/GNP)

Digitally based controls are having a profound impact on energy efficiency and productivity.

The potential for energy savings from application of digital technologies has only begun to be tapped, as illustrated by the growing number of semiconductor-based, energy-saving, digital technologies described below. Through a combination of improved communications, control, and energy conversion, these technologies offer energy savings ranging anywhere from 25% to 70% in an increasing array of end-use devices.

Energy-Efficient Digital Lighting

Lighting systems use approximately a third of the electric power in the U.S., and energy efficiency improvements in this area are at the forefront. Microprocessors have enabled a host of new digital technologies improving energy efficiency and productivity, including:

Occupancy Sensors

These sensors use ultrasonic or infrared methods to detect movement. They can be installed in conference rooms, closets, individual offices, break rooms, or restrooms to turn lights off when these spaces are not occupied. If the lights in these areas are generally left on, occupancy sensors can reduce lighting costs up to 40%.

Electronic Ballasts and T-8 Lamps

Fluorescent fixtures may have older magnetic ballasts and T-12 lamps. Replacing them with electronic ballasts and T-8 lamps can reduce lighting costs up to 30%.

LED Exit Signs and Traffic Lights

The light emitting diode (LED) is an important semiconductor technology. Lighting fixtures made with LEDs can replace incandescent lights in exit signs and traffic lights, reducing energy costs by up to 95%. Since exit signs and traffic lights typically run constantly, the much longer life and higher efficiency of LED fixtures mean substantial energy and maintenance cost savings. As shown in Table 1-2, the application of microelectronics to lighting has a profound impact on energy

Table 1-2
Return on Investment in Digital Lighting

Lighting Investments	Annual Return on Investment
Occupancy Sensors	55 – 70%
Electronic Ballasts and T-8 Lamps	25 – 35%
LED Exit Signs	30 – 40%

Improved Efficiency through Digital Environmental Control

The added control and data exchange capabilities of digital technologies offer a virtually limitless range of applications for improving the monitoring, control, and comfort of living and work spaces.

As shown in Table 1-3, digital energy efficiency technologies have a lot to offer in improved air conditioning efficiency. Although more conventional measures, such as higher efficiency air conditioners and evaporative systems, offer significant benefits, digital energy management and motor drive systems can do even more.

Table 1-3
Return on Investment from Digitally Controlled Air Conditioning (Source: EPA Energy Star)

Air Conditioning Investments	Annual Return on Investment
High-Efficiency Air Conditioners	25 – 35%
Evaporative Coolers	25 – 35%
Energy Management System (EMS)	30 – 40%
Adjustable-Speed Drives (ASDs)	30 – 40%
High-Efficiency Motors	35 – 45%

Programmable Thermostats

These simple digital devices provide extensive control over when air conditioning is on and what temperature is maintained. Set points can be made responsive to time-of-day, seasons, occupancy, and even real-time price signals from the local power provider.

Energy Management Systems (EMS)

Energy management systems incorporate computers and digital sensors and can control entire buildings or individual workspaces. They are especially useful with modern air conditioning systems, which are too complex to control with simple time clocks. They allow unique cooling and heating temperatures for different zones, optimum equipment start and stop times, and control strategies that keep building occupants comfortable while minimizing energy use.

Fans Controlled by Adjustable-Speed Drives (ASDs)

Air conditioning systems all contain fans that move air throughout a building. The operating cost of these fans can be profoundly reduced by installing adjustable-speed drives (ASDs), digital motor controllers that change the speed of the fan to precisely match the amount of air that is needed, thereby eliminating waste and improving efficiency.

Energy Efficient Digital Office Equipment

Every modern workplace is festooned with computers, printers, copiers, faxes, and a world of other productivity digital devices. Microprocessors, while enabling these technologies to begin with, are also making them significantly more efficient. Monitors and computers represent 1% of the country's electricity use, according to the Environmental Protection Agency (EPA), but computers and monitors that are left on overnight or that don't use the sleep mode feature waste about half of that output. Research by Lawrence Berkeley National Laboratory (LBNL) in Berkeley, California, reveals that about 70% of monitors and 55% of computers used by U.S. businesses and government offices are left running idle after hours.[4]

Microprocessors, while enabling sophisticated office technologies to begin with, are also making them significantly more efficient.

A number of digital energy-saving technologies have been promoted by the EPA's Energy Star™ program, providing further example of how digital technologies are now being employed to *reduce* energy use:

- Energy Star PCs have a power down feature automatically engaged during periods of inactivity, reducing energy costs up to 50%.
- Energy Star monitors automatically power down when not in use, saving up to 80% of energy costs.

[4] Emelie Rutherford, "Save Power, Save Money," CIO Magazine, August 1, 2001 (http://www.cio.com/archive/080101/tl_save.html).

- Energy Star printers power down when inactive, cutting energy costs up to 65%.
- Energy Star fax machines have power management features that can reduce energy costs up to 50%.
- Energy Star copiers can automatically turn off after a specified period of inactivity, reducing energy costs up to 60%.

Microprocessors, while enabling these technologies to begin with, are also making them significantly more efficient. A number of digital energy-saving technologies have been promoted by the EPA's Energy Star program, providing further example of how digital technologies are now being employed to *reduce* energy use. As shown in Figure 1-5, Energy Star copiers can automatically turn off after a specified period of inactivity, reducing energy costs up to 60%

Figure 1-5
Microprocessors Reduce Energy Use in Office Equipment (Source: EPA Energy Star)

Energy Efficient Computers

Computers are often presented as bad actors in the energy efficiency world. In fact, some experts have estimated that Internet-related computers, telecommunications, and networking devices siphon off 3 to 8% of the nation's electricity. The worst culprit, these experts say, are "server farms" that house rows of computers that run Web sites and other business operations and can draw 10 megawatts (or more)—enough electricity for 10,000 homes.[5]

This, however, doesn't tell the whole story, as digitally driven innovation on a number of fronts is already changing the energy use of server farm/co-location businesses. For example, Energy Star has recently recognized IBM Corporation for designing its z900 eBusiness enterprise server, show in Figure 1-6, to use much less energy than its predecessors.[6] A single z900 server can be divided into tens, hundreds, or even thousands of virtual servers, each running separate applications simultaneously. While a typical configuration of 750 Sun servers costs approximately $620/day in electricity to run, a single z900—running the same workload—costs only $32/day, a power saving ratio of nearly 20 to 1. The savings are even more dramatic when floor space requirements of a server farm are considered. The average server farm requires some 10,000 square feet of floor space compared with only 400 square feet for a single IBM z900. At an average of 100 watts per square foot, the savings can be significant.[7]

[5] Edward Iwata, "Experts square off over Net's role in Calif. power crisis: Are computers fueling a productive economy or are they energy hogs?" *USA Today*, January 22, 2001, MONEY, Pg. 1B.
[6] *Government Computer News*, "An Energy Star," Patricia Daukantas, September 10, 2001; Vol. 20 No. 27.
[7] *Government Computer News*, "An Energy Star," Patricia Daukantas, September 10, 2001; Vol. 20 No. 27.

Figure 1-6
Digital Energy Efficiency of the IBM z900 (Source: IBM)

While the IBM z900 saves energy at the system level, other companies are working to make individual microprocessors much more energy friendly. One company that touts its microprocessors as energy misers is Transmeta Corporation of Santa Clara, California. Transmeta's Crusoe processor uses a combination of hardware and software to cut power. The Crusoe chip has about one-third as many logic transistors as a conventional processor. It gets around this potential limitation by using a simple but powerful 128-bit instruction set called VLIW, for "very long instruction word." A layer of software mediates between a 32-bit operating system and VLIW. A power management utility called Long Run adjusts the power and performance of the Crusoe 200 times per second to accommodate the application running on the chip.[8]

The energy efficiency gains from these microprocessors have been impressive: A Pentium-class computer with a 15-inch LCD monitor uses only 25 watts—a fraction of the 350 watts used by a typical PC with a CRT.[9]

Another comparison contrasted energy uses of a TM5800 Crusoe processor operating at 800 MHz with a Pentium-III ULV (ultra low voltage) running at 600 MHz. In a Ziff-Davis BatteryMark Comparison, the PIII chip burns 2.12 watts where the Crusoe burns 0.91 watt, both running at full speed, a reduction in energy use of 57%.[10]

The first systems with Crusoe chips began arriving about a year ago, most of them portable computers from Asian manufacturers, and volume shipments of the chips began in 1Q 2002. Crusoe chips are also going into ultra dense servers such as those from RLX Technologies, Inc., of Houston. Crusoe-based servers can be packed together more closely than others.[11] Figure 1-7 shows the Crusoe TM5600 and TM5800 processors.

[8] *Government Computer News*, "An Energy Star," Patricia Daukantas, September 10, 2001; Vol. 20 No. 27.
[9] *Government Computer News*, "An Energy Star," Patricia Daukantas, September 10, 2001; Vol. 20 No. 27.
[10] "Era of constrained power" dawns Jerry Ascierto, *EE Times,* October 16, 2001.
[11] *Government Computer News*, "An Energy Star," Patricia Daukantas, September 10, 2001; Vol. 20 No. 27.

Figure 1-7
Transmeta Crusoe Chips Offer Energy Efficiency (Source: Transmeta)

Productivity Improvement and IMPROVED Product Quality through Digital Technology

Microprocessors have made significant contributions to improved productivity and improved product quality in the U.S. and around the world. However, traditional economic measures of productivity alone do not reveal the full extent of contributions by advanced digitally driven manufacturing technologies to the nation's economic progress. Over the past five years, those benefits amounted to nearly $1 trillion.[12]

Digital Productivity

Several recent studies have concluded that contributions to enhanced productivity in traditional manufacturing equaled—and may have exceeded—those of the high-tech sectors, including computers and information technologies. A new study, "Producing Prosperity - Manufacturing Technology's Unmeasured Role in Economic Expansion,"[13] goes further in illustrating and explaining why the remarkable growth in durable goods-producing industries, with a rate of increase in real output between 1992 and 1997 about twice the rate of the overall economy, provides a fuller measure of the benefits associated with advanced manufacturing technologies.[14]

Figure 1-8 shows that the gain in the manufacturing sector has arisen entirely in the durable goods sector; non-durable MFP has been flat for about a quarter of a century. Much of this growth in productivity is attributed to the application of digital technologies to the manufacture of non-computer products.

[12] Association for Manufacturing Technology, "Producing Prosperity – Manufacturing Technology's Unmeasured Role in Economic Expansion," Joel Popkin and Company, Washington, D.C., September 28, 2000, http://www.mfgtech.org/Publications/productivity.html

[13] Association for Manufacturing Technology, "Producing Prosperity - Manufacturing Technology's Unmeasured Role in Economic Expansion." Joel Popkin and Company, Washington, D.C., September 28, 2000, http://www.mfgtech.org/Publications/productivity.html

[14] Association for Manufacturing Technology, "Producing Prosperity – Manufacturing Technology's Unmeasured Role in Economic Expansion," Joel Popkin and Company, Washington, D.C., September 28, 2000, http://www.mfgtech.org/Publications/productivity.html

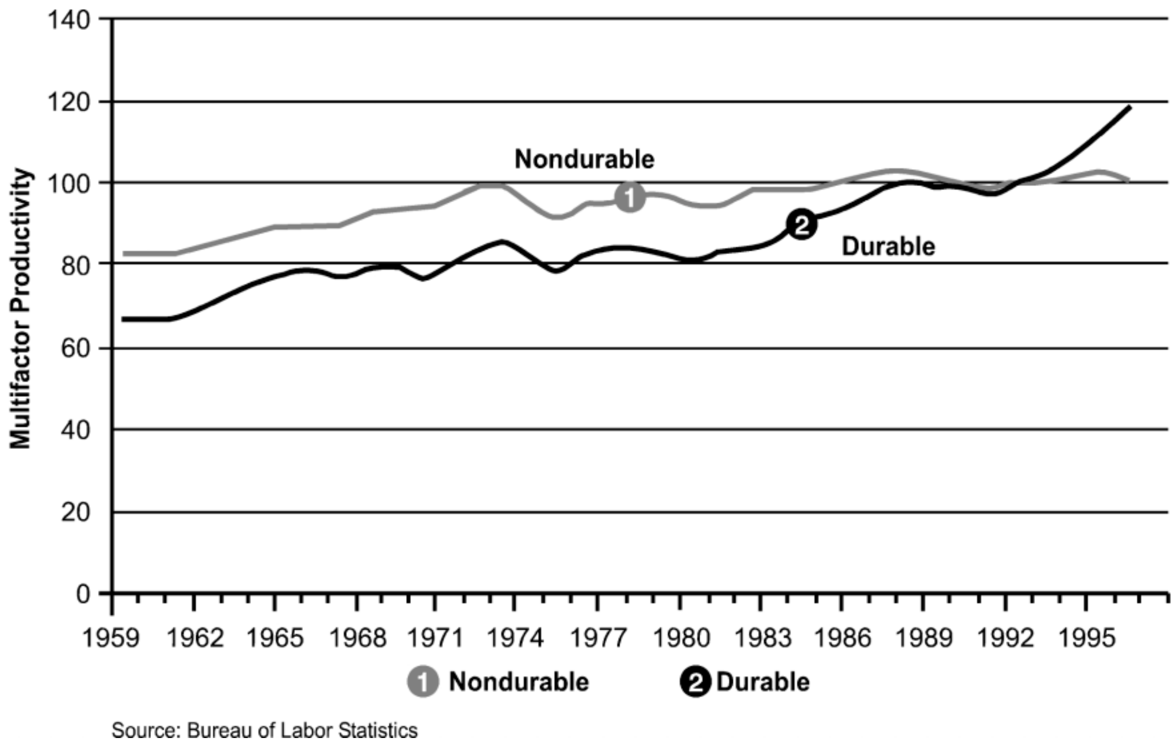

Figure 1-8
Multifactor Productivity (MFP) in the Digital Age

The durable goods producing industries have grown twice as fast as the economy as a whole due to benefits associated with advanced manufacturing technologies.

The study also reveals that between 1959 and 1996, manufacturing productivity grew about 40% faster than productivity in the overall non-farm economy, as measured by multifactor productivity (MFP), a fundamental measure that considers factors beyond capital and labor. Between 1992 and 1996, durable goods manufacturing (such as autos, appliances, and aircraft) achieved MFP gains averaging 4.2% annually.[15]

"For the last several years, a puzzling gap has existed between what traditional economics was telling us about productivity and what the economy has actually done," said Association for Manufacturing Technology President Don F. Carlson. "This study allows us to see the light. Moreover, because it is focused on only the manufacturing technology industry, this study may well be only the tip of the iceberg," Carlson continued. "It is likely that other manufacturing industries have a similar tale to tell."[15]

[15] Association for Manufacturing Technology, "Producing Prosperity – Manufacturing Technology's Unmeasured Role in Economic Expansion," Joel Popkin and Company, Washington, D.C., September 28, 2000, http://www.mfgtech.org/Publications/productivity.html

Digitally Fueled Gains in Product Quality

Intense global competition has led to advances in production automation and product quality. In the aerospace industry, for example, McDonnell Douglas Corporation took advantage of advanced high-speed machining, operating 15 times faster than a previous method, to improve the manufacturing process for landing-gear bulkheads on the C-17 aircraft. With the new process, McDonnell Douglas makes bulkheads with two parts rather than 72, and with only 35 fasteners rather than 1,720 as under the previous method.[16]

Intense global competition has led to advances in production automation and product quality.

Digitally driven productivity gains in manufacturing have fostered enormous benefits:

- Rapid gains in labor productivity in the durable goods sector generated an additional $618 billion of output (in 1996 dollars) over 1992-1998.
- These same producers saved $25.3 billion in carrying costs between 1992 and 1997, thanks to a decline in inventory requirements per dollar of sales attributable to advanced manufacturing processes. This frees up capital for additional investments.
- Eight key industries saved a combined total of $24.3 billion in payroll costs in 1997 alone—and $80 billion between 1992 and 1997—because of productivity increases. They include auto parts, aircraft engines and parts, engines and turbines, metal foundries, fabricated structural metal, other industrial machinery, construction and mining equipment, and farm and garden machinery.
- The cost of consumer durable goods from 1996 to 1999 was just over $100 billion less than it would have been without these gains, and purchases of imports would have risen more than they did.
- End users are saving billions from product quality improvements such as cars with higher fuel efficiency ($50 billion in 1999).[17]

Quality improvements are especially dramatic in the automobile industry. The Bureau of Labor Statistics between 1967 and 1998 reports an average quality improvement rate of 2.2%, resulting in higher quality, longer-life products. For example, today's automobile—designed and manufactured with increasingly digital technology—has twice the quality of one built 30 years ago in terms of performance, reliability, durability, and warranty (see Figure 1-9). As a result, today an owner of a new car produced by U.S. companies experiences fewer than 30 problems per 100 vehicles during the first year of ownership compared with a rate of 104 per 100 cars in 1980. That higher quality translates into significant consumer savings as a result of fewer repairs

[16] Association for Manufacturing Technology, "Producing Prosperity – Manufacturing Technology's Unmeasured Role in Economic Expansion" September 28, 2000.
[17] Association for Manufacturing Technology, "Producing Prosperity – Manufacturing Technology's Unmeasured Role in Economic Expansion" September 28, 2000.

and longer useful life. Car maintenance costs dropped 28% between 1985 and 1998, saving consumers $21 billion in 1998 alone.[18]

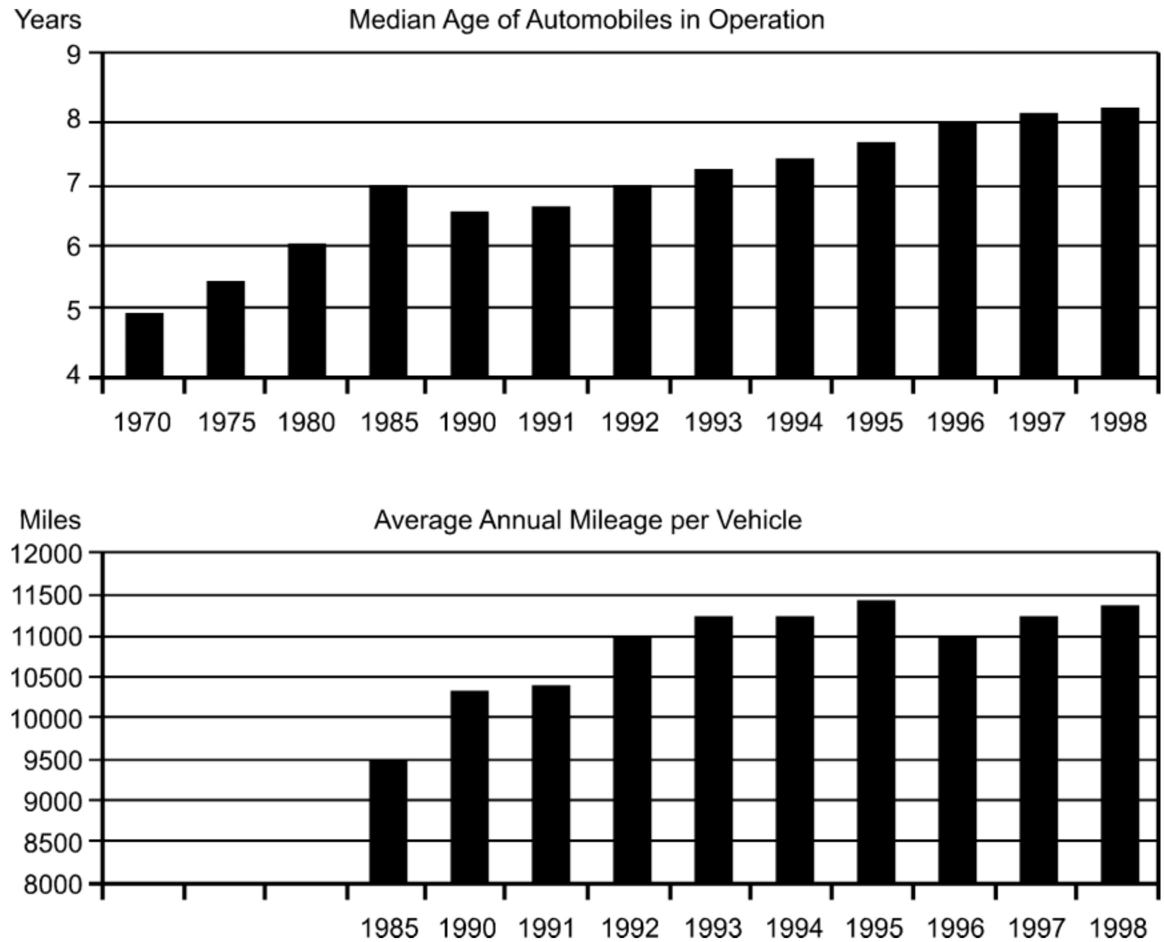

Figure 1-9
Today's Automobiles Last Longer (Association for Manufacturing Technology)

In addition to fueling a good portion of America's economic expansion during the last 10 years, digitally driven advances in manufacturing technology have provided other macroeconomic benefits. They have:

- Improved the quality and prosperity of the nation's workforce by making it necessary for employers to provide workers with more training. Workers who improve their skills qualify for higher wages and improve their living standards.
- Reduced the peaks and valleys of the U.S. business cycle, perhaps avoiding (or reducing the depth of) economic recessions by smoothing out inventory fluctuations. Better machine tools have helped shorten process times and aided just-in-time inventory management procedures.
- Restored the U.S. as a powerhouse in the global marketplace. The recent growth in volume of American exports far outpaces those of Germany and Japan, among others. Between 1986

[18] Association for Manufacturing Technology, "Producing Prosperity – Manufacturing Technology's Unmeasured Role in Economic Expansion" September 28, 2000.

and 1996, U.S. exports of manufactured products grew at an average annual rate of 10%, compared with 4% for Germany and 2.5% for Japan.

Beneficiaries of these advances, understated above, have included nearly everyone:

- Manufacturers, who make higher quality products faster and at lower cost.
- Consumers, who pay less for higher quality goods that perform better and last longer.
- Workers in the manufacturing sector, who acquire new skills and earn higher real wages.
- The economy, because the U.S. is competitive and inflation stays in check.

The Economic Impact of Microprocessors and Other Chips

In 1998, one digital industrial sector, the U.S. electronics industry, generated approximately 1.2 million jobs and US$300 billion.[19] In 1999, U.S.-based companies supplied more than 55% of the world's semiconductor processing equipment (worth about $12.9 billion) and held 25% of the world market for digital manufacturing processing and packaging materials, worth more than $5.5 billion.[20] Every cellular call, every Internet click, and every computer cycle was made possible by advances in the equipment or materials that make integrated circuits. In 1999, semiconductor equipment, materials, and services—a $65 billion industry—drove the semiconductor manufacturing industry—a $141 billion industry—which in turn enabled over $836 billion of sales in electronics worldwide.[21]

Clearly, the importance to modern economies of microprocessors and other semiconductors is profound and is likely to continue to be so. For example, progressively cheaper and more powerful chips are enabling the U.S. electronics industry to be more competitive—U.S. chipmakers regained their position as the most competitive manufacturers in the world, capturing nearly 50% of the world's semiconductor market in 2000.[22] An expected rise of 15% in global chip sales in 1999 and 21% in 2000 should fuel accelerated growth in capital spending. The global market for semiconductor equipment is forecast to rise 8.8% in 1999, to $23.4 billion. Of this total, the U.S. market is expected to account for approximately 34% of sales or $7.9 billion, representing an increase of 5% over 1998. The global market for materials used to make semiconductors is forecast to rise about 10% in 1999, to $22 billion. The U.S. market for semiconductor materials comprises about 28% of the world total, or $6.2 billion.[23]

The U.S. electronics industry generated approximately 1.2 million jobs and US$300 billion in 1998.

[19] Semiconductor Industry Association, "SIA 2001 Annual Report."
[20] Semiconductor Equipment and Materials International, "SEMI 1999 Annual Report: The Power of Global."
[21] Semiconductor Equipment and Materials International, "SEMI 1999 Annual Report: The Power of Global."
[22] Semiconductor Industry Association, "SIA 2001 Annual Report."
[23] Semiconductor Equipment and Materials International, "SEMI 1999 Annual Report: The Power of Global."

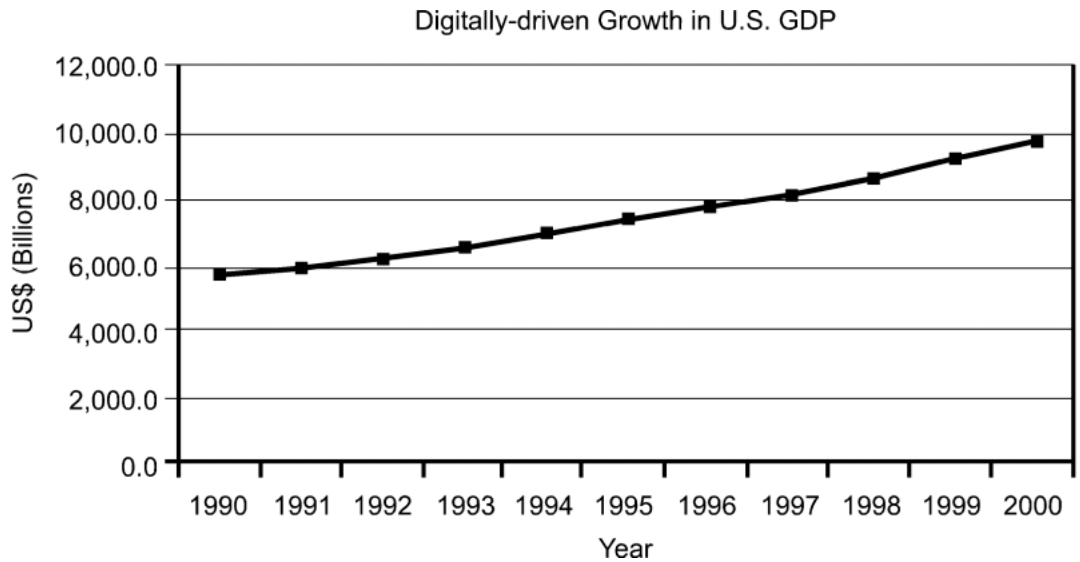

Figure 1-10
Growth in U.S. Gross Domestic Production (Source: U.S. Department of Commerce, Bureau of Economic Analysis)

The development of digital technologies has been a power engine for modern economies. In 2000, the U.S. semiconductor industry invested 14¢ for every dollar of sales in research and development, a higher percentage than any other American industry and three times the industrial average. Such investments are likely to continue improving the lives of people around the globe with products and services enhanced by the microchip. These chips are everywhere, and their numbers keep growing. As shown in Figure 1-11, in 2001, approximately 60,000 transistors were produced for each human living on Earth. By 2008, this annual production is expected to increase by 17-fold, to one billion transistors per person.

The pace of semiconductor innovation is fast, and getting even faster. New technologies are now introduced every two years, one year faster than the traditional rate under "Moore's Law" (see Figure 1-12). Now, microprocessor speed doubles every four years. Every five years, manufacturers increase tenfold the number of bits, or units of memory, that are produced. Today's microcircuits routinely contain hundreds of millions of transistors per chip, connected by patterns that rival a street map of Earth in complexity.[24]

[24] Semiconductor Industry Association, "SIA 2001 Annual Report."

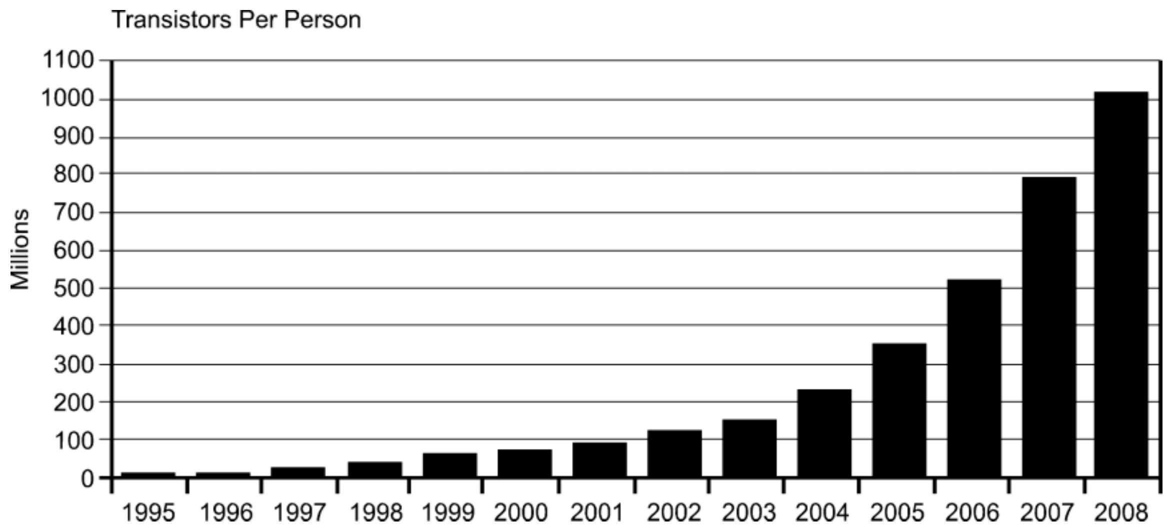

Figure 1-11
World Transistors versus World Population (Source: Semiconductor Industry Association)

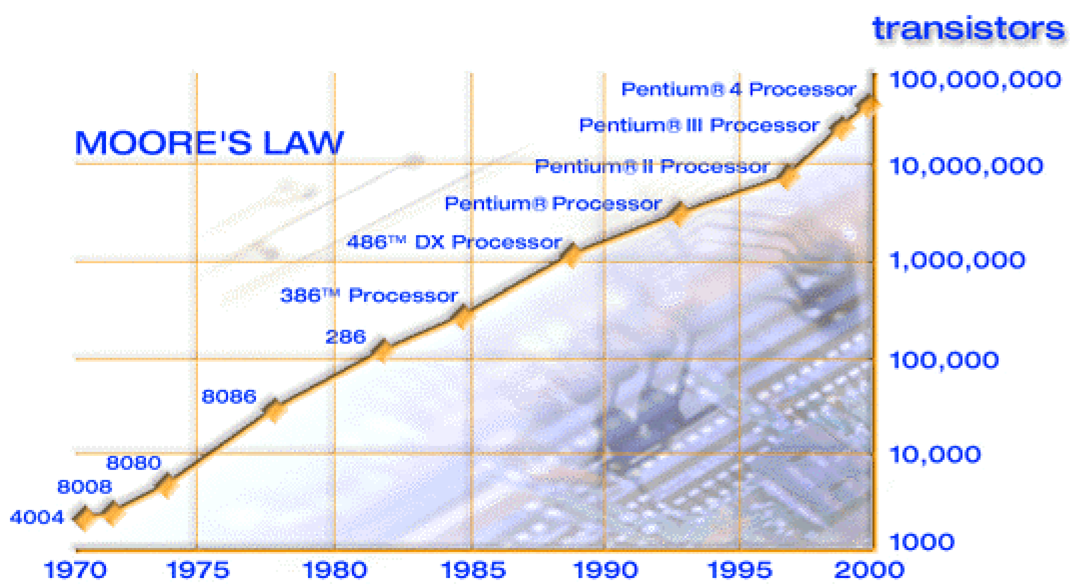

Figure 1-12
Moore's Law of Digital Innovation

The power dissipation of modern processors is rapidly increasing along with the clock frequency speed (MHz) and the number of transistors required for a given implementation. Figure 1-13 shows the power consumption trend of processors introduced by Intel®, a major microprocessor manufacturer, over the past 15 years. As can be seen, while there are a few spikes, the general trend is for maximum processor power consumption to increase by a factor of a little more than two times every four years.

The increase in power usage has so far helped decrease the processing times of operation; but at the same time, there is a growing disparity between the maximum power consumption of a processor and the "typical" power consumed by that processor. This trend is the result of the significant increase in transistor count required to attain the desired peak performance targets.

- PCs (CPU and monitor) are estimated to account for only 2% of all residential electricity use in 2000
- PC CPU, monitor, and laser printer are estimated at 3% of commercial electricity used
- Power consumption by mainframes and microprocessors declined by 50% between 1990 to 2000 while the density of the chips have increased by up to 30% (see Figure 1-13).[25]

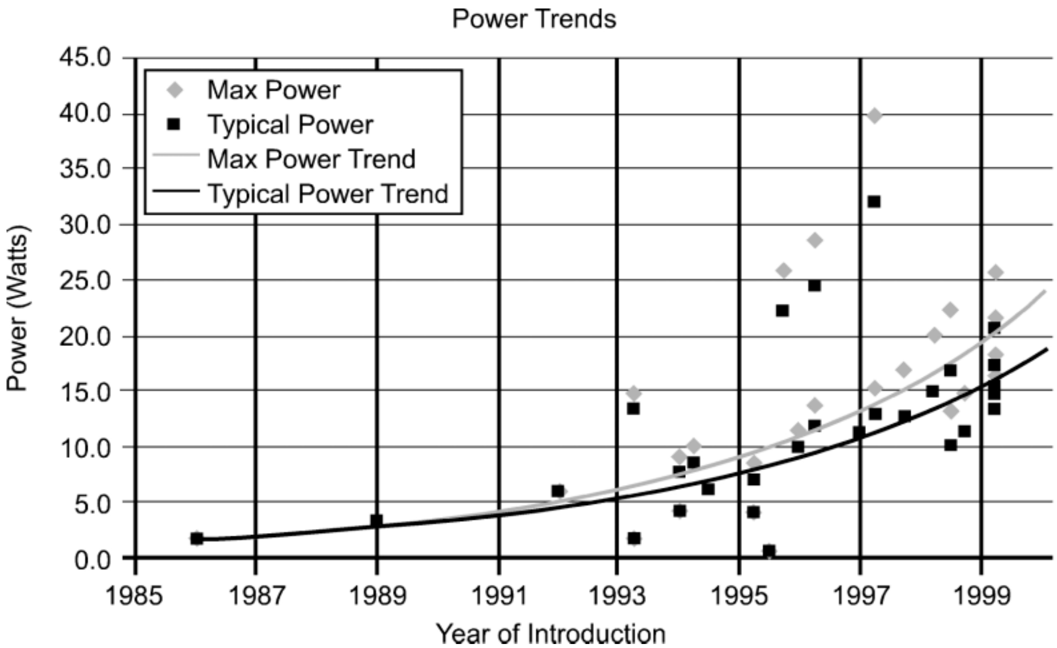

Figure 1-13
Trends in CPU Power Consumption

Chip designers are currently designing processors with the intent of minimizing recurring system costs, especially those arising from high power consumption, while retaining a high level of reliability. This requires attention to details at all stages of the design. Reducing power consumption, without negatively influencing either the performance or reliability of the processor in any significant way, is a major challenge, with millions of dollars dedicated for research each year.

The Importance of Electric Power SQRA for Digital Processes

Digital controls have added intelligence and flexibility to virtually every segment of modern economies. This is nowhere truer than in modern, high-tech manufacturing, where digital controls have increased the precision and productivity of countless processes. Today's electronic digital controls are everywhere—motors, lighting, HVAC—saving energy, increasing process productivity, and enabling these and other systems to become "Smart Utilization Equipment" in homes, offices, and industrial plants.

[25] Source: http://developer.intel.com/technology/itj/q12001/articles/art_4c.htm, viewed May 25, 2001.

Security

Maintaining the security of electric power supplies to these systems will become increasingly important in years to come. An EPRI survey of electric utilities revealed real concerns about grid and communications security. Figure 1-14 shows the ranking of perceived threats to utility control centers.[26] The most likely threats were bypassing controls, integrity violations, and authorization violations, with four respondents in ten rating each as either a 5 or 4 out of 5. Concern about the potential threats generally grew as the size of the utility (peak load) grew. In addition, utilities were asked to rank the types of intruder threats. Just under half of the respondents expressed concern over the threat of hackers and/or disgruntled employees. Other potential intruder threats were significantly likely to be rated as concerns.

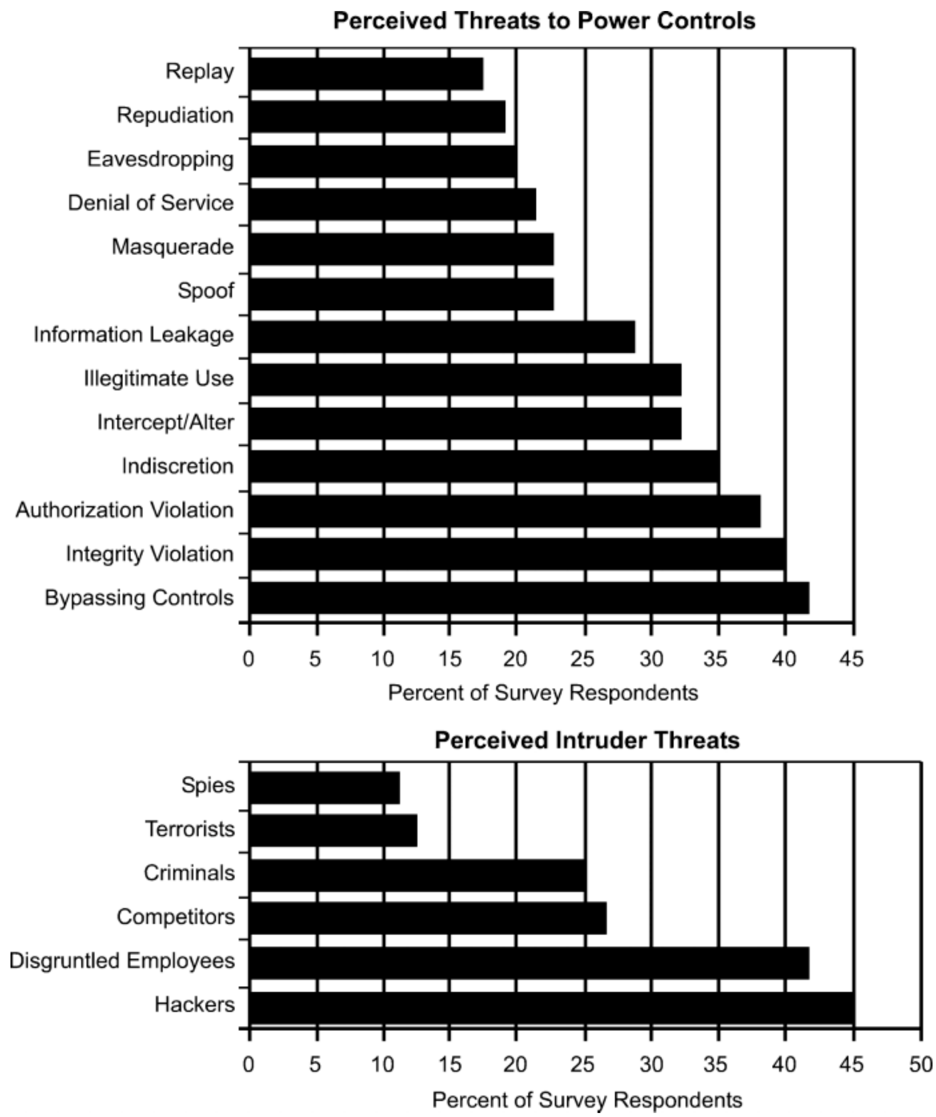

Figure 1-14
Threats to Power Supply Control According to the Results of an EPRI Survey

[26] W. Blair, EPRI, "Communication Security Assessment for the United States Electric Utility Infrastructure," (December 2000), EPRI Document #1001174, pg. 4-11.

Quality, Reliability, and Availability

Sags in voltage supplied to digital systems are a growing concern, and one of the most common causes of problems. One reason these sags are an increasing concern is that the amount of sensitive equipment that modern businesses use—including programmable controllers, adjustable-speed drives (ASDs), and computers—has increased dramatically. U.S. sales of microcomputers—those most likely to be employed in industrial settings—have nearly tripled since early 1993. Then, sales were just under 1.2 million units per quarter; in late 1998, sales were nearly 3.2 million units per quarter (see Figure 1-15).[27]

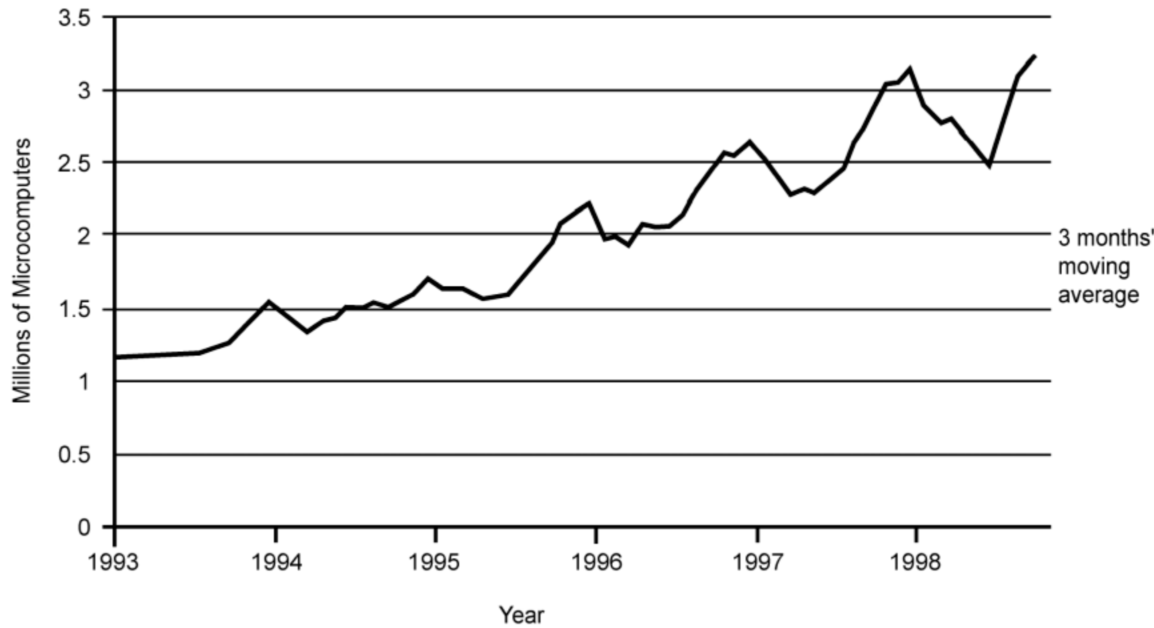

Figure 1-15
The Increasing Use of Microelectronics

Providing end users with electric power that is free from voltage sags would seem to be the obvious responsibility of the local utility. Utility folks and electrical engineers have a saying: "The utility owns the voltage, and the end user owns the current"—meaning that the utility is responsible for generation, distribution, and regulation of the *voltage* at an end user's meter, but the end user's load is what characterizes the shape of the electrical *current*.

The challenge facing the utility side of this partnership is this: the voltage a utility "owns" is usually generated at power plants dozens (or hundreds) of miles from the loads the utility serves. Between power generation and the load, there is a wide array of systems and devices including transmission lines, substations, switches, reclosers, step-down transformers, distribution systems, and interconnections with other utilities' grids.

Electric power delivery plays a pivotal role in the ability of digitally controlled processes—whether discrete or continuous—to deliver on the promise of improved productivity. In fact, as

[27] "Microcomputer Unit Shipments in the United States, Total Industry Shipment Estimates, November 11, 1998," Information Technology Industry Council (ITIC), United States Microcomputer Statistics Committee, Washington, DC.

shown in Table 1-4, the presence of electrical disturbances can easily reduce the productivity of digitally controlled processes by 5 or 6% and as much as 9%.[28]

Table 1-4
The Impacts of Electrical Supply Disturbances on Manufacturing Processes

Manufacturing Metrics	Production Results with no Electrical Supply Disturbances	Production Results with Electrical Supply Disturbances	Percent Impact
Number of Parts Produced	66,644	65,111	-2.3
Average Time (min) in System	10,012	10,802	-7.9
Resource Utilization (%)			
Stamping	0.99	0.96	-3.1
Welding	0.55	0.51	-7.8
Assembly	0.86	0.8	-7.5
Painting	0.55	0.52	-5.7
Inventory Levels			
Stamping	6,648	7,257	-9.1
Welding	0.23	0.25	-8.6
Assembly	0.63	0.68	-7.9

Field tests and simulations have shown that the degradation to the performance of manufacturing processes can be significant due to expected electrical disruptions. The percent degradation numbers may be deceptive because these values represent the significant impact that electrical distributions have on the production line. For example, a 9.1% increase in inventory space requirement is a significant additional cost to the organization. This cost includes components such as facility cost ($70 per square foot), utilities cost (heating, cooling, lights), labor cost (additional labor to handle inventory), equipment cost (additional material-handling equipment), and others. It is also evident from the simulation results that electrical disturbances degrade every critical performance metric of a production line. These degradations would significantly increase from the above results given the following realistic conditions:

The complexities of optimally interfacing digitally controlled processes with electric power supply cannot be overstated. Even local utility and customer equipment can be the source of problems for digital technologies that are not properly isolated or otherwise buffered from power supply issues.

[28] M. Howard, T. Key, R. Sawheny, “Evaluating Industry Specific Electrical Disturbances Using A Process Modeling and Simulation Tool,” EPRI PQA Conference, 1999.

Two common culprits in locally induced power supply problems are electric motors and transformers, both common and ubiquitous in industrial, commercial, and utility systems. Electric motors, in particular, can cause problems such as voltage sags when started, due to their large “inrush” currents. Energizing large transformers can also cause voltage sags that might upset digitally controlled processes. Figure 1-16 shows how such a motor start can cause a 9% voltage sag.

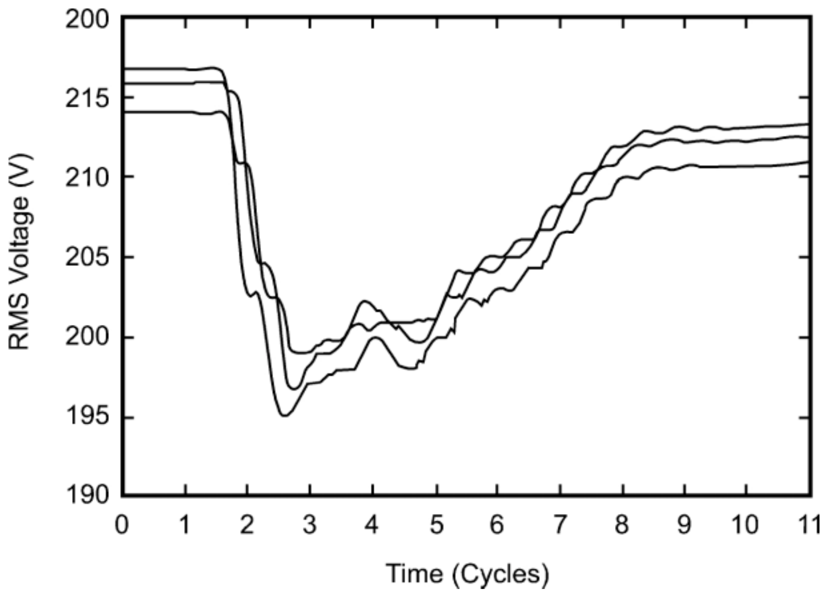

Figure 1-16
The Effects of Motor Starting on Supply Voltage[29]

Digitally Enabled Applications

All echelons of society—residential, commercial, and industrial—are benefiting from the application of digital technologies. In fact, the demand for chips continues to grow exponentially, as shown in Figure 1-17. Establishing an unambiguous definition of “digital end-use” equipment is critical to activities such as load forecasting, load modeling, research in power quality, and research in reliability and availability. The usual approach is to define digital systems at the “micro end-use level”—for example, computers, servers, routers, LAN switches, and any other information technology equipment that uses binary (digital) bits (0s and 1s) for its operation. However, sometimes ignored are loads that are traditionally not associated with information technology but are, in their modern forms, digitally enabled or controlled, and which may completely reprocess standard 60-Hz power.

Typical applications include electronic-based office information technology equipment in commercial business and Internet data center (IDC) equipment. Also included are electronic-based equipment in residences, such as home office, home entertainment, and household appliances. This class further includes the application of IT in electronic automation equipment used in industrial plants and processes such as programmable logic control and machining numerical control.

[29] M.H.J. Bollen, “Voltage Sags in Three-phase Systems,” (September 2001), *IEEE Power Engineering Review,* Vol. 21, Number 9, pg. 9.

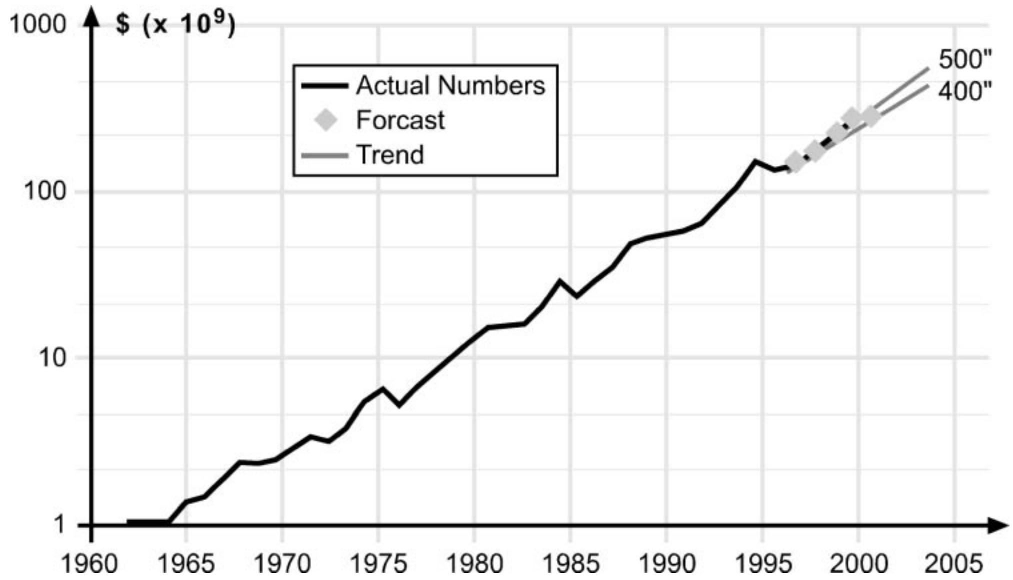

Figure 1-17
The Exponential Demand for Chips[30]

A vast array of consumers, enterprises, and businesses now benefit from the capability manifest in the digital revolution. Here are a few examples:

The Digital Residence

Imagine that you come home from work and as you approach the house, a retinal analyzer recognizes you, opens the door, and greets you by turning on the lights. In the kitchen, you walk towards your fridge, which informs you that you are missing a few ingredients from the recipe for tonight's dinner. You enter the living room, where your latest e-mails await you on your television set. At the same time, without you even knowing it, your dishwasher has detected an internal technical fault and has automatically requested maintenance assistance from its manufacturer.

This is how it might be living in a "smart" house, a house that demonstrates interactivity and reactivity. In the smart house, all elements are interconnected (microwave, washing machine, surveillance cameras), and all are linked to networks like the Internet and are configurable and monitorable from anywhere in the world (see Figure 1-18).

[30] Prof. Dr. Helmut Föll, University of Kiel, Germany, http://www.techfak.uni-kiel.de/matwis/amat/elmat_en/makeindex.html, March 15, 2002.

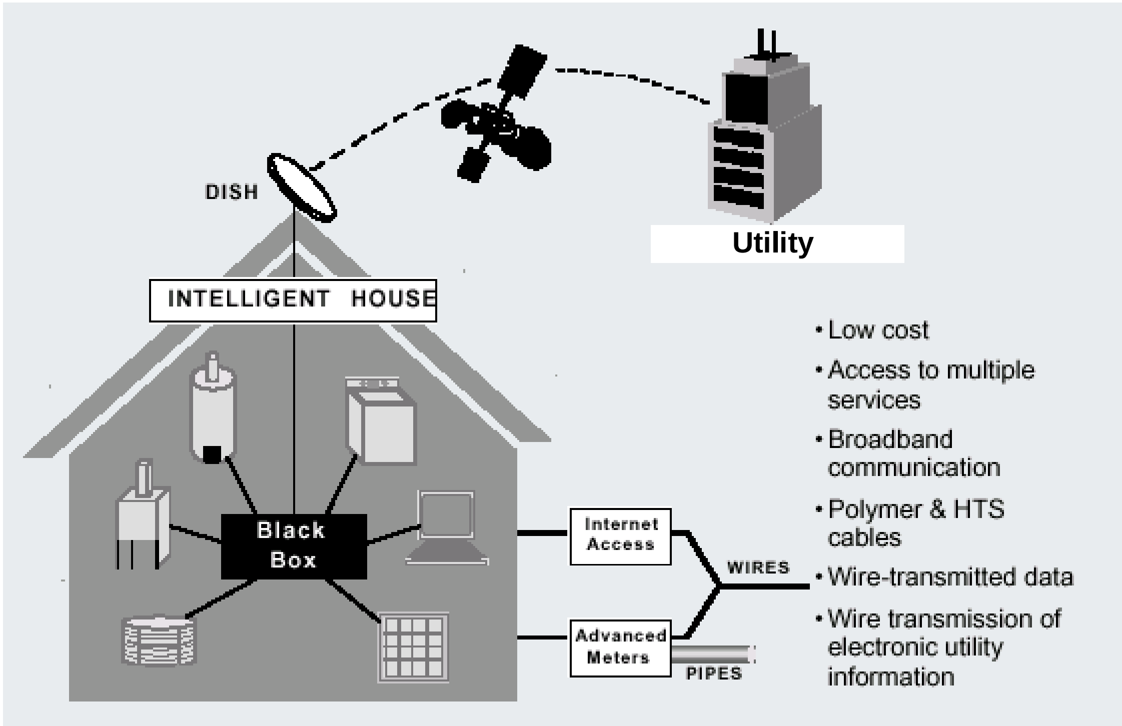

Figure 1-18
A Smart House

If South Korea's LG Electronics has its way, your refrigerator will soon be used for much more than storing milk. The company unveiled a new Internet-ready refrigerator that can be used to surf the Web and even make telephone calls.[31] The result of a three-year, 55 billion won (US$49.2 million) project staffed by a team of 55 researchers, the "Internet Digital DIOS Refrigerator" features two prominent 15-inch TFT (thin film transistor) liquid crystal display panels (LCDs) on its front, one on each of the two main doors.

Through these panels, users can access a range of high-tech features, such as a database of real-time grocery prices, health and nutrition tips, and cooking information. And, if users first tell the refrigerator what goods are being stored inside, it alerts them as expiration dates come closer. To connect to the Internet, the unit features a broadband connection; a video camera is built in just above one of the screens to allow users to videoconference or take images and send them via e-mail. LG said they plan to begin selling the product at a price of 9.9 million *won* (US$8,850). While several manufacturers have shown prototypes of such kitchen appliances, this is the first time that a major electronics maker has commercialized an Internet refrigerator. The company said it has submitted applications for 75 patents both in and out of Korea as a result of the project.

LG Electronics, a major global player in electronics and telecommunications, operates 72 subsidiaries around the world with over 55,000 employees worldwide. LGE focuses on Digital TV, CD-RW, DVD, CD-ROM, DVD-ROM Drives, PCs, Monitors, Mobile Handsets, CRTs, and PDPs. LGE is strengthening core competencies even more to further its reputation as the "Digital

31 http://www.idg.net/idgns/2000/06/23/LGLaunchesInternetRefrigerator.shtml, Martyn Williams, IDG News Service/Tokyo Bureau, June 23, 2000, 02:51.

Leader" in electronic products and equipment in the digital era. LGE's Digital Refrigerator, shown in Figure 1-19, incorporates web monitoring and control, as well as network access and interface with other web-enabled devices, such as LGE's Digital Air Conditioner. Both products are expected to hit the market in March 2002.

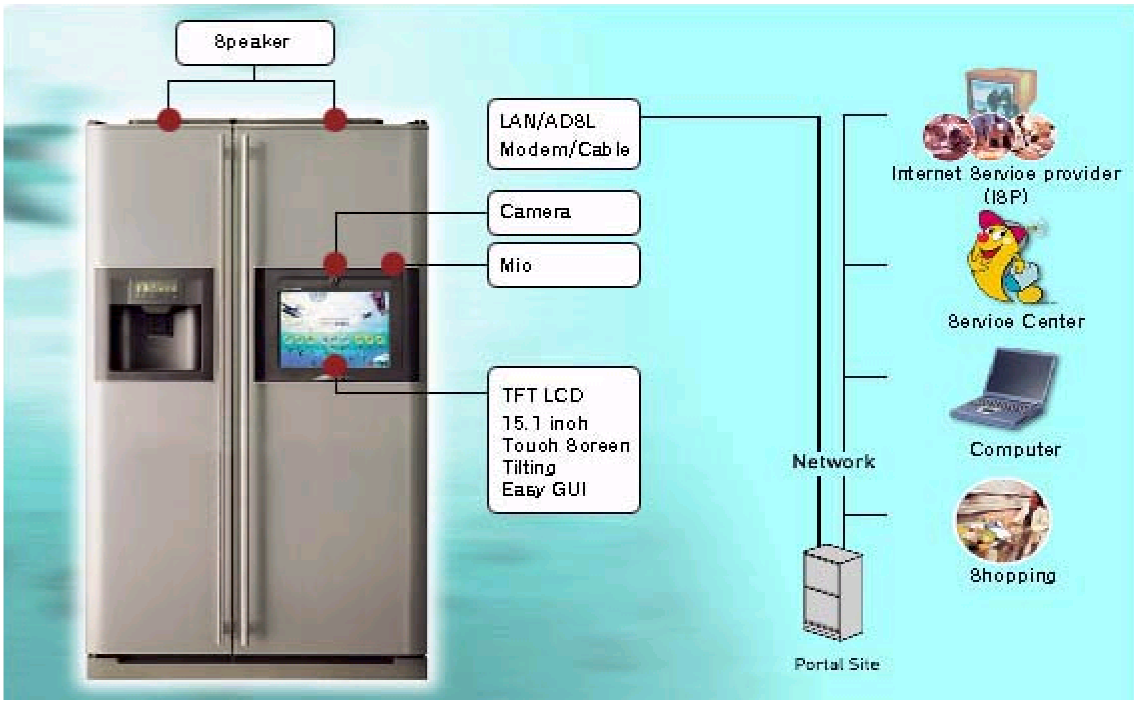

Figure 1-19
Example of a Networked Appliance (Source: LG Electronics, www.lge.com)

Digitally Enabled Office Equipment

Few venues have more aggressively embraced the digital future than the workplace, as enterprises both large and small have come to recognize the powerful advantages that products using digital technology offer over their lower-tech, analog counterparts. Vendors within this space, whose new modular multifunctional copier systems include optional printer, fax, scanner and PC-fax modules, are setting the standard for digital office solutions designed for smaller workgroups. There are six major benefits to digital technologies:

- Modularity: When a machine is capable of supporting a range of functions, users may upgrade it by adding modules, such as a printer, a fax, a scanner, or a PC-fax module, to keep their office technology in step with their needs.
- Versatility: The digital equipment is capable of precise customization to match user requirements.
- Connectivity: Critical as it enables digital office equipment to be connected into a computer network, allowing a range of efficiencies in the office, such as "multiple original printing." (This is when a number of sets of a document are printed off as originals instead of first printing and then copying the master version, saving considerable time, effort, and cost.)

- Reliability: Thanks largely to fewer moving parts in digital office equipment, the technology is more reliable. This means more uptime and, hence, improved productivity and reduced frustration.
- Quality: Digital technology allows excellent quality copy, print, and fax reproduction without the degradation usually associated with the copying process.
- Creativity: Digital copying technology gives the user the facility to edit and manipulate copied images easily and flexibly, meaning they need never again be reduced to having to copy an unsatisfactory image.

The energy used by digital office equipment is significant, providing further evidence of the technology's important role in digital society (see Table 1-5).

Table 1-5
Annual Energy Use for Office Equipment in 1999 (TWh/Year) (Source: LBNL[32])

Equipment Type	Residential	Commercial	Industrial	Total
Portable Computer	0.14	0.13	0.02	0.29
Desktop Computer	2.67	10.21	1.46	14.34
Server	0	1.60	0.23	1.83
Minicomputer	0	8.86	2.95	11.81
Mainframe	0	5.62	0.63	6.25
Terminal	0	1.83	0.61	2.44
Display	3.13	9.82	1.40	14.35
Laser Printer	0.10	5.36	0.77	6.23
Inkjet/Dot Printer	1.10	1.56	0.22	2.88
Copier	1.10	5.71	0.82	7.63
Fax	0.44	2.26	0.32	3.02
Totals	8.67	52.95	9.42	71.04

Like e-mail, digital copiers have developed a firm foothold in most office environments, making them a logical center for copying, printing, and document distribution. The digital copier was first introduced to the market as a standalone device in 1985, and it was not until 1990 that a connectivity option for digital copiers became available. The first digital copiers were prohibitively expensive for all but the high-end segments of the copier market. As increased

[32] Kaoru Kawamoto, Jonathan G. Koomey, Bruce Nordman, Richard E. Brown, Mary Ann Piette, Michael Ti ng, and Alan K. Meier, "Electricity Used by Office Equipment and Network Equipment in the U.S.: Detailed Report and Appendices," LBNL-45917, Lawrence Berkeley National Laboratory, Calif., September, 2001, **http://enduse.lbl.gov/Info/Pubs.html**.

competition and decreased manufacturing costs have driven down the price of digital copiers, their sales across all market segments have dramatically increased. In fact, Dataquest predicts that sales of digital copiers in the U.S. will reach approximately 1.8 million (or about 90% of the U.S. copier market) by the year 2003, due largely to the many perceived benefits the technology offers business (see Figure 1-20). With the introduction of the connectivity option, the digital copier was truly able to leverage its multifunctional capabilities of printing, faxing, and scanning and position itself as a key player in the emerging "digital office."

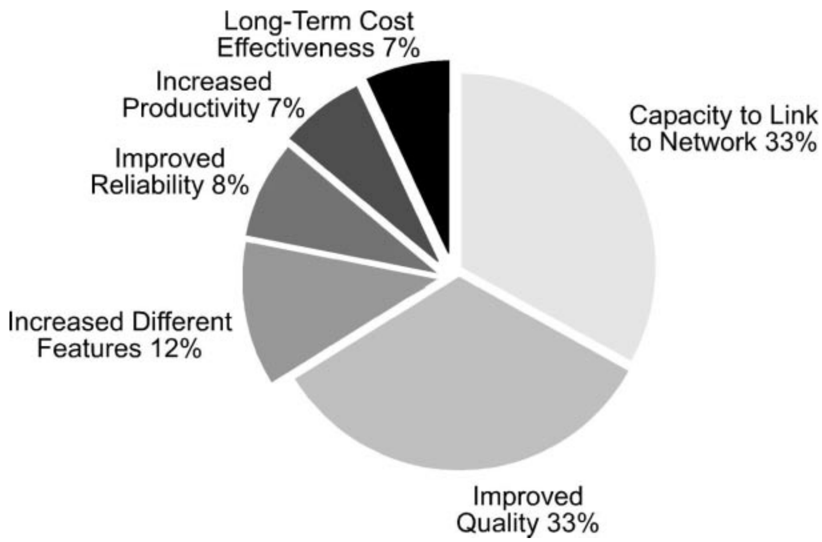

Figure 1-20
Reasons for Purchasing Digital Copiers (Source: DataQuest)

Digitally Enabled Manufacturing

Although manufacturing processes are not as glamorous as rooms full of Internet servers or smart, web-enabled appliances, the digital revolution is at work at every level of the manufacturing sector. In 1993, the U.S. Census Bureau conducted a *Survey of Manufacturing Technology*, collecting information about the use of certain digital technologies and asking companies why they were installing the equipment. In particular, companies reported on the single most important reason for using a given technology. The study found that not only are manufacturing businesses making aggressive use of digital technologies, they are doing so primarily to improve quality and output—both important contributors to productivity (see Table 1-6).

Table 1-6
End-User Reasons for Using Digital Technologies (Source: U.S. Census Bureau)

Technology	Percent of Plants Using Technology	Percent Distribution by Most Important Reason				
		Improved Quality	Increased Output	Lower Labor Cost	Other	Not Specified
CAD/CAE	57.9	24.9	24.7	3.1	3.0	2.1
CAD/CAM	25.3	10.5	10.3	2.3	1.0	1.3
Digital Data Representation	11.2	5.8	3.2	0.9	0.8	0.4
FMC/FMS	12.6	3.5	5.0	2.5	0.8	0.8
NC/CNC	46.3	16.0	19.9	6.0	1.5	2.9
Materials Working Lasers	4.9	2.2	1.1	0.6	0.7	0.3
Pick and Place Robots	8.5	1.5	3.3	2.9	0.3	0.5
Other Robots	4.7	1.3	1.5	1.4	0.2	0.3
Programmable Controllers	29.9	11.1	9.9	2.6	3.4	2.8

The Internet

Perhaps the best example of the impact of the digital revolution on enterprise is the capabilities made manifest in the Internet. In many respects, the progress of the digital wave can be tracked by plotting the progress of the Internet, a sector that has grown at an annual rate of over 60% since 1995 (see Table 1-7). By the end of 1992, there were only 50 web sites in the World and a year later; the number was still no more than 150. Hosted sites on the Internet have grown at an average rate of 66% since 1995. While the Internet is often held up as representing “The” digital revolution, it actually is best perceived as perhaps only its most obvious manifestation, as an enormous variety of businesses and enterprises have contributed to the system’s growth as they have caught the wave of the digital revolution. The Internet itself hasn’t spawned web sites. Rather, it has been businesses, governments, and individuals who, empowered with digital technologies and capabilities, have made the digital revolution a reality.

The number of Americans using the Internet has grown from fewer than 5 million in 1993 to as many as 62 million by 1997. The number of names registered in the domain name system (DNS), which is the way that Internet domain names are located and translated into Internet Protocol addresses, grew from 26,000 in July 1993 to 1.3 million in four years. Over the same period, the number of hosts connected to the Internet went from under 2 million to over 20 million. At this rate, the projected number of hosts connected to the Internet by the summer of 2001 will exceed 130 million.

The speed with which the Internet allows people and enterprises to interact and to share information and data typifies the high rate of change facing infrastructure resources such as electric power. The Internet never sleeps, and users expect it to be available not just most of the time, but *all* the time, without exception and without excuses. This capability serves as example and harbinger of the digital revolution. As shown in Figure 1-21, the growth of the Internet has ridden on microprocessors and the digital technology that they enable.

Table 1-7
The Growth of Internet Hosts Since 1995

Date	Hosts	Percent Change
January-95	5,846,000	--
July-95	8,200,000	
January-96	14,352,000	146%
July-96	16,729,000	
January-97	21,819,000	52%
July-97	26,053,000	
January-98	29,670,000	36%
July-98	36,739,000	
January-99	43,230,000	46%
July-99	56,218,000	
January-00	72,398,092	67%
July-00	93,047,785	
January-01	109,574,429	51%
	Average	66%

- Estimated Internet Host Growth
- Hosts - A computer system with registered IP address (an A record)
- Data collected from the Internet Software Consortium: www.isc.org

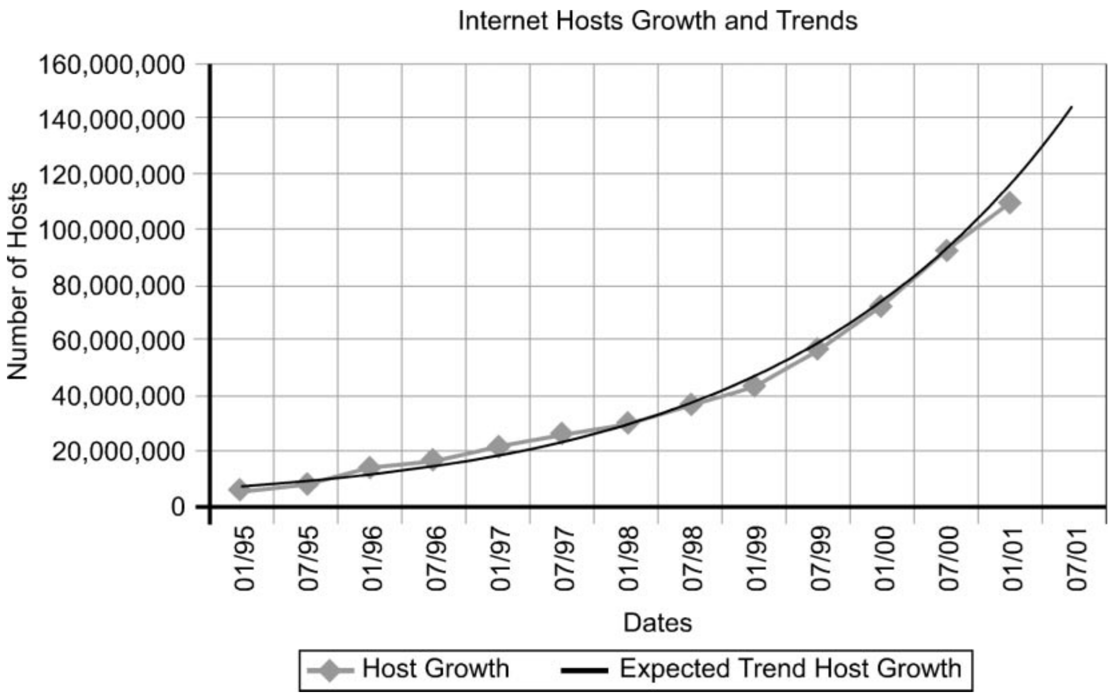

Figure 1-21
Internet Host Growth and Trends

Another harbinger of the digital society is having people—all sorts of people in all walks of life—using digital technology, services, and capabilities in day-to-day activities. The Internet again provides a convenient example of how digitally enabled enterprise is taking root. As shown in Figure 1-22, the growth in use of digital communications is exploding, nearly doubling from 1999 to 2000.

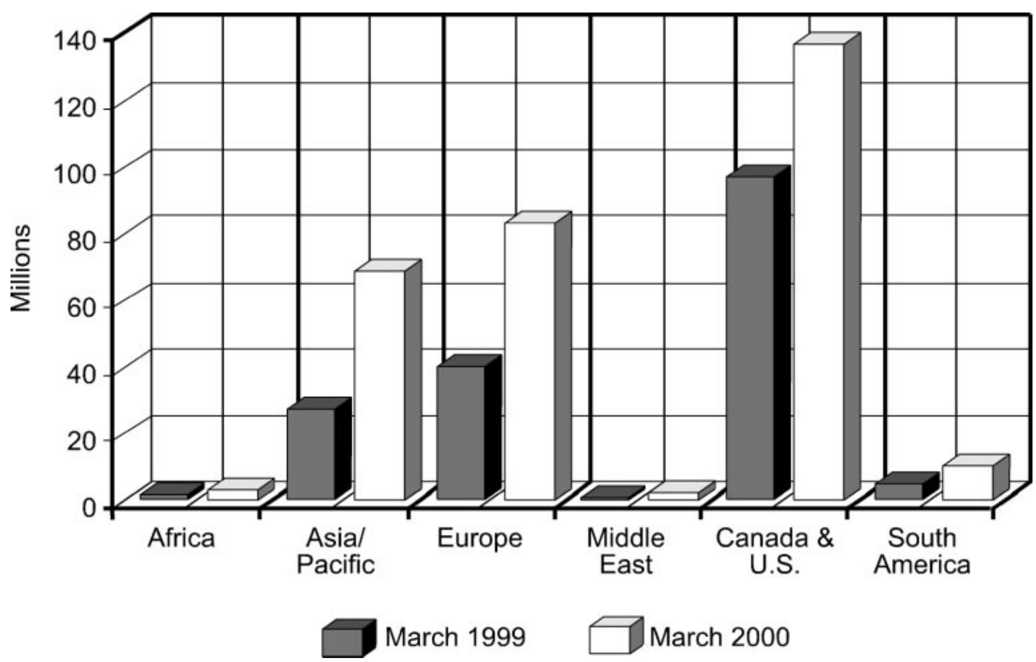

Figure 1-22
Explosive Growth of Numbers of People with Internet Access

2

DEFINING DIGITAL ENERGY APPLICATIONS AND END-USE

The digital revolution has spawned changes in electric power use patterns, requirements, and expectations related to the digital economy. These changes are presenting formidable challenges to the interface between electric power delivery systems and digital systems, processes, and enterprises. In order to meet future challenges of planning, providing infrastructure, and serving this new economy, better methods are needed to recognize and measure this change. Digital business is a new paradigm and none of the conventional business measurement systems provide the whole story. It is multi-dimensional and all these dimensions must be accounted for in order to forecast the electrical impacts. The objective of this chapter is to define electric energy use in the digital society.

Characterizing Digital End-Use Equipment

Establishing an unambiguous definition of digital end-use equipment is critical to activities such as energy and demand forecasting, end use modeling, research in power quality, and research in reliability and availability. The usual approach is to define digital end-use equipment at the micro end-use level by the nature of the equipment and the way the equipment is applied. In this case, we recognize computers, servers, routers, LAN switches, and other front and back information technology equipment as obviously digital.

By this method we assert that data processing equipment—or any equipment that uses binary (digital) bits of information (0s and 1s) for its operation—can be generally categorized as digital end-use equipment. For example, an Internet data exchange facility is clearly a digital society business that consists of primarily digital devices. The nature of the digital equipment is primarily electronic, microprocessor-based, volatile and non-volatile memory storage media, displays, and input/output hardware. In this case, the digital applications processing 0s and 1s are data communications, storage, processing, and routing.

Still another valid approach, particularly from the power delivery point of view, is to distinguish digital systems, processes, and businesses by their electrical characteristics. When a factory is transformed from a manual labor-intensive operating mode to a completely automated operating mode, the local power provider may measure many of the same electrical load characteristics as data processing customer loads. Probably the utility will experience at least some of the same demands and complaints for “digital-quality power” as received from an Internet facility end user. But is the factory now a digital system?

Even these two distinctions for defining digital end-use—digital equipment processing of 0s and 1s and digital electronics electrical characteristics—do not provide the complete picture. How about loads that are traditionally not associated with information technology or with electronic load characteristics but are, in their modern forms, digitally enabled or controlled, and may completely reprocess standard 60-Hz power to complete a particular task? This category is real and clearly deserves additional analysis and recognition.

Need for Better Agreement

The shift to more digital businesses is changing the variables used by electric utilities to balance generation and demand in the business of electric power delivery. Certainly, we have seen that load density and usage patterns change when the load is more digital. In many ways, the digital economy will make electricity more valuable—from this it might be argued that more resources can be invested in power delivery.

Looking at it another way, the lack of electricity, or even the lack of quality in the electricity product, can be a lot more costly in a digital economy than in prior evolutions of electrical end use. And what about technological changes that bring more emissions in the form of harmonic distortion and higher frequency electrical noise? A functional aspect of the digital economy, combining power and communications, will also bring new sensitivity and upset levels to digital systems.

Clearly, there is a need to define and forecast digital energy use. At the present time, there is much confusion as to exactly what *is* the electrical consumption of digital loads. For example, there has been a point of contention between Lawrence Berkley National Laboratory, Mark Mills, and others regarding what percentage of existing loads can be considered as digital. Once again, the answer will really depend on the definition of what *is* a digital load. Once the definition for different end-use digital loads has been established, then data from Department of Commerce and Department of Energy end-use load surveys can be used to identify what percentage of existing loads can be considered as digital.

Once the baseline for existing digital load has been established, we need to answer the question, “What is the forecasted growth of digital loads?” If information technology (IT) loads alone are considered as digital loads, then a relatively straightforward technique of researching the expected growth level of future applications and IT companies can be used to create a forecast of the future load growth. However, all of our research indicates that this is too narrow a definition of digital end use. We have already witnessed the emergence of digitally enabled processes and new digital enterprises that are beyond the definition of IT. Once again, depending on how a digital load and digital end use are defined, the forecast will be different.

The best way of forecasting digital loads, once a definition has been established, is to conduct market research on publicly available documents from industries that are involved in production of digital loads to estimate the forecasted load growth. Other macro-level national indicators, such as gross domestic product (GDP), can be used for the forecast; however, the accuracy of the forecast will largely depend on the accuracy of the other variables that will be used for making the assumption. For example, just last year, the forecasted growth for CISCO, one of the largest manufacturers of digital economy loads, was estimated as 30% and above. In just one year, that forecast has now been changed to less than 15% sequential growth, year after year for the next several years.

There are several ways to define and measure energy use related to the digital society. In the following sections, we will define digital energy use based on segmenting the many parts of the digital economy into three main classes: digital equipment, digitally controlled processes, and digitally enabled businesses.

At this time, standardized methods and databases are not available to support accurate end-use estimates of all the many dimensions of the digital society. The definitions offered here are intended to identify some of the data that are needed to improve our ability to predict and measure this emerging area of energy use.

Digital or Not?

The Introduction to this report cites many examples of old and familiar appliances now evolving to become more digital. Consider today's home refrigerator: what would make it a digital device? Electrically, we would say this is not a digital load, because the motors that drive the compressor and the fan do not use digital bits of 0s and 1s. Also, the end product is refrigeration, not information or data processing. Now consider the next generation of refrigerators, which have a connection to the Internet and sensors in different compartments that automatically notify users when food expires or needs to be replenished. The electric power to the compressor and fan are converted to variable voltage and frequency to optimize the use of electric energy. A control panel can be interrogated to determine operating history and status.

Taking an end-use viewpoint, this modern refrigerator still appears to be a non-digital load. It has a normal plug connection and the same non-digital, non-IT end product of providing refrigeration. It looks and acts almost identical to the traditional refrigerator. However, there are a number of important differences, and these differences may eventually distinguish the modern refrigerator as a digital load.

The modern refrigerator is clearly smarter—it provides a lot of information about food inventory, usage, and temperature. It has memory and can report the age, remaining freshness, and schedule for replenishment of the perishable foods. Temperature and humidity controls not only signal the time to start and stop, but also set operating levels to conserve energy or maximize performance depending on the chosen program. These are all characteristic traits of digital loads.

But the "smart" refrigerator may also be more vulnerable to variations in electric energy due to its microprocessor and other sensitive electronic circuits. For example, a voltage sag can cause a control malfunction in the smart refrigerator, whereas the traditional refrigerator would likely continue to operate normally. With the introduction of digital control, the power quality requirement of the modern refrigerator is quite different from the requirement of the traditional refrigerator.

Characteristics of Digital End-Use Equipment

Focusing on the electrical characteristics or physical nature of digital end-use equipment rather than application, we can identify some unique characteristics compared to non-digital equipment. Generally we characterize this equipment as electronic or electronic data processing (EDP), a designation that is used in several national codes and standards related to equipment classification, labeling, premises wiring, and installation. More specifically, we identify this equipment as nonlinear, sensitive to environment, and critical to continuous and error-free data processing. These are technical classifications that can be misunderstood or misapplied. Therefore, clarification of these physical descriptors of digital end-use equipment is a good starting point.

Linear versus Nonlinear Equipment

A common confusion related to digital electronic equipment is whether every nonlinear electronic load is digital or if digital electronic must be nonlinear. The answer is no, not necessarily. But, before making this distinction, it is useful to describe exactly what is meant by nonlinear.

Nonlinear is an electrical characterization that simply describes how the applied voltage, provided by the power systems, compares to the current drawn by the connected equipment. Another way of showing the linear nature of the load is to look at how the load impedance changes relative to the applied voltage. This can be an important characteristic for utility companies responsible for serving this equipment. Utilities design their delivery systems to maintain a certain impedance, and they understand that the relationship of the voltage and current for electrical equipment depends on the impedance of the equipment. This is best described by a picture. Note in Figure 2-1 and Figure 2-2 the expected voltage and current waveforms for two well-known *linear* loads—incandescent lamps and motors.

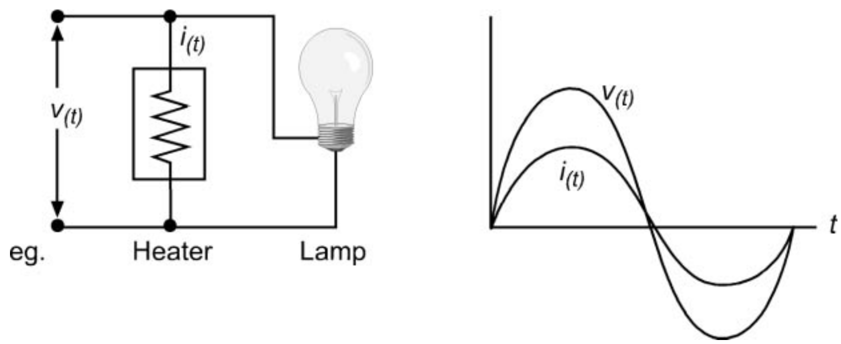

Figure 2-1
Incandescent Lamps Are Resistive Loads

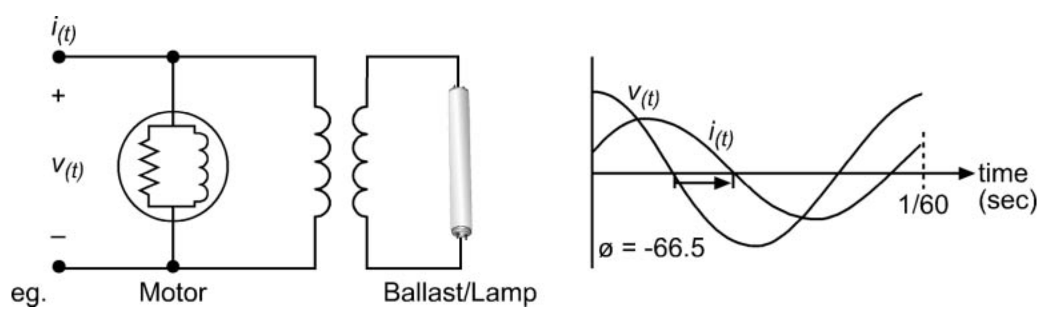

Figure 2-2
Motors Demonstrate Both Resistive and Inductive Characteristics

The lamp and other resistive loads are usually considered as ideal, in that voltage and current are not only identical, but the watts consumed are also equal to the voltage times the current. This characteristic is called unity power factor, or a power factor of 1.0. In the case of a motor, where the voltage and current are not in phase, the power factor is less than one. This means that the watts consumed are less than the voltage times the current required from the electric service. Both of these electric loads are recognized as linear because the shape of the current follows the shape of the voltage. When this occurs, the level of harmonics in the power system is very low.

Digital load is often nonlinear. As shown in Figure 2-3 and Figure 2-4, the current waveform does not match the voltage waveform. This load characteristic, referred to as nonlinear, creates harmonics in power systems. The harmonics increase losses in power delivery, and higher levels can cause power delivery problems and even disruption of power service. In all cases, the harmonics are of some cost to power delivery and local distribution.

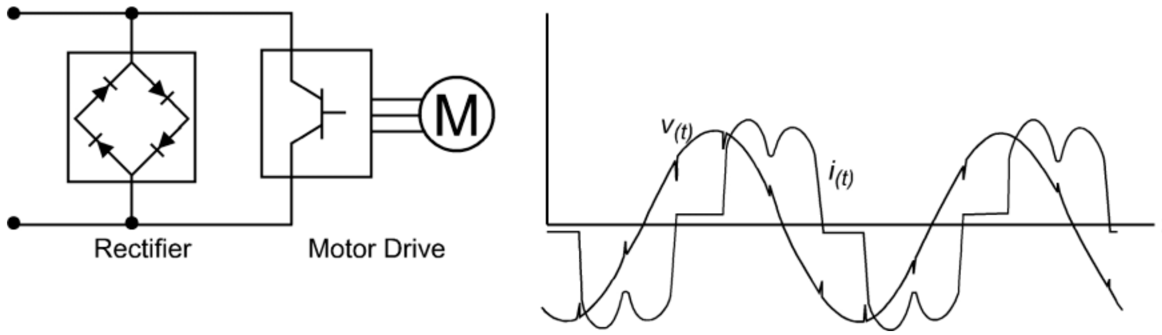

Figure 2-3
Power Electronic Equipment such as Motor Drives, Battery Chargers, and Large Computers Draw Nonlinear Current

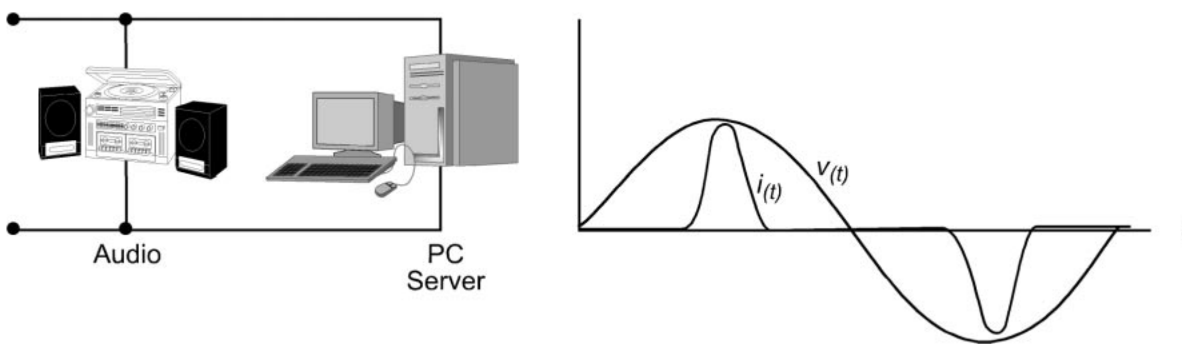

Figure 2-4
Personal Computers, Monitors, Routers, Servers, and Types of Video and Audio Equipment Draw Nonlinear Current

The National Electrical Code, in the articles that address equipment installation, defines electronic equipment and devices based on whether the load is linear or nonlinear. Article 100 states that the following definitions are commonly used:

Linear load. An electrical load device that in steady state operation presents an essentially constant load impedance to the power source throughout the cycle of applied voltage.

Nonlinear load. A load where the wave shape of the steady-state current does not follow the wave shape of the applied voltage.

In the NEC, a fine print note (FPN) states: “Electronic equipment, electronic/electric-discharge lighting, adjustable-speed drive systems, and similar equipment may be nonlinear loads.” And the following comment is included in the Code: “The definition of nonlinear load was added to Article 100 in the 1996 Code. Nonlinear loads are a major cause of harmonic currents in modern electric circuits. Information on the undesirable operational effects that are often associated with harmonic currents, including additional heating, was also added in the 1996 Code.” The FPN following Section 310-10 (on wiring practices) points out that harmonic current as well as fundamental current should be used in determining the heat generated internally in a conductor. Also, limited use of parallel neutrals (over-sizing to account for harmonics) is permitted in Section 310-4, Exception No. 4.

Since the use of nonlinear loads can directly affect heating in building wiring and transformers, it is reasonable for the NEC to point the finger at digital electronic equipment. When we apply a narrow definition of digital loads that encompasses only information technology equipment, computers, servers, monitors, and the like, *all* digital loads are nonlinear. Nonlinear loads are characterized by higher RMS currents, which indicate the heating effect of these load currents. In fact, we have shown in evaluations of commercial building wiring (EPRI PQTN Commentary No. 1, *Harmonic Currents in Commercial Buildings*, December 1996) that these nonlinear loads may increase building wiring losses by 2.5 times.

Clearly, harmonic distortion in digital load equipment is a key defining characteristic. However, it is an oversimplification to say that *all* electronic equipment is nonlinear and *all* nonlinear equipment is electronic. Consider a very simple load—a light dimmer, which uses silicon-controlled rectifiers to chop the voltage and thereby control the light output of the bulb. This device is a nonlinear load because the current drawn by the dimmer is nonlinear. But is this load digital? Because there is no digital control associated with the circuit of a light dimmer, it seems an unlikely candidate for the category of loads called "digital."

On the other hand, consider a device widely used to control the speed and torque of a conventional induction motor, the adjustable-speed drive (ASD). This is a nonlinear load because the power electronics required to convert the incoming AC voltage to a DC voltage creates nonlinear current. However, unlike the light dimmer, the ASD is controlled by a microprocessor, which is a rather obvious example of digital load technology. Despite their both being nonlinear loads, the light dimmer may not rightfully be labeled a digital load, whereas the ASD, or at least the ASD controller, can be.

Just as not all nonlinear loads will be digital, looking further at example loads, we can also conclude that not all digital loads are nonlinear. For example, the Internet-enabled refrigerator discussed in the Introduction, from an electrical point of view, represents a mostly linear load. However, because of the embedded microprocessor-based control, it may be classified as a digital load.

One trend to watch in the future is that today's nonlinear power supplies, called switch-mode power supplies, used in most digital electronic loads, will be linear. This technology change is simply a different front-end for the equipment's power supply at the point that the equipment is connected to the AC-electric power system. New linear power supply technology is being driven by standards limiting harmonics, particularly from the International Electrotechnical Commission and the European Community. The technology is now available. However, incentives for IT manufacturers to make these changes are lacking. This is why standards that limit harmonics are the strongest driver for linear power supplies.

Shift in Characteristic Impedance

Another important and distinguishing characteristic of all end-use load equipment is the impedance that is presented to the power system serving that equipment. Simply stated, impedance is the relationship between the voltage and the current of a connected load. Impedance can be estimated by applying a particular voltage and measuring the resulting current.

As discussed above, the load's impedance is often used to identify it as linear or nonlinear. In the linear load**,** the electrical device presents essentially constant load impedance to the power source throughout the cycle of applied voltage; therefore, the current tends to follow the voltage. With a nonlinear load**,** the wave shape of the steady-state current does not follow the wave shape of the applied voltage, and the nonlinear load current is discontinuous or is not proportional to the AC voltage.

The nature of the load impedance will determine how a particular end-use load will react to changes in the applied voltage. For example, the power consumed by simple linear loads such as incandescent lamps and resistive heaters responds directly to voltage changes. A 4% reduction in voltage causes a 4% reduction in the current drawn by the device. Since the power in a resistive device depends on the current squared, the change in power consumption caused by the voltage reduction can be estimated as a reduction of 16%.

Energy consumption in other load equipment such as electric motors will follow the applied voltage, but not directly and not linearly. For example, a reduction in the voltage on a motor that is serving a constant load may result in an increase in the current with little change in power consumption. If the motor is driving a fan or other variable load, then a reduction in voltage can reduce real power consumption. However, this is not the whole story. Complex loads such as motors and fluorescent lighting have two power components—real power and reactive power. Since the reactive power demand will affect losses in power systems, the impact of the voltage on the reactive power must also be considered.

In the case of electronic loads, the real and reactive power demands are a matter of power supply design. Many electronic products are constant power devices. For example, computers, electronic ballasts, and adjustable-speed drives tend to act as constant power loads, and changes in voltage will not affect the power consumption. On the other hand, voltage level and power supply loading will likely change the harmonic levels and losses in both the power supply and the power delivery system. These variations can be attributed to the nonlinear impedance of electronic equipment, and any predictive models of expected load response to power system voltage change will require consideration of these impedance changes.

Potential Impact on Electric Power Delivery Infrastructure

Another reason to better predict trends in digital end-use equipment is the potential impact on the electric power delivery infrastructure. As has been discussed, much of the new digital equipment is additional to equipment in the existing power system infrastructure. A good example is the typical office of the 1960's: lights; HVAC;[33] and convenience outlets for appliances such as an electric typewriter, coffee pot, and clock—total energy required was 4-5 watts per square foot. Today, a typical office has all the same appliances, except instead of the typewriter at a few desks, we find many workstations with computers, printers, monitors, servers, copiers, and fax machines. The total energy required has increased to 10-12 watts per square foot.

The new digital equipment in offices increases the electrical loading, adds harmonics, and represents a change in characteristic impedance and is, therefore, impacting the power system performance. Old transformers may be overloaded by these new electronic systems. Building wiring, in particular neutrals carrying the harmonic currents of modern loads, may be reaching the thermal limits. In cases of energy saving appliances, the amplitude of electric current may

[33] Heating, ventilation, and air-conditioning

actually go down as digital end-use equipment is added. These differences are relative, and impacts may be subtle or grow slowly over time. All indicators show continued growth of digital end-use. Forecasting this growth and providing better characterization of the nature of the new loads is needed so that power system planners may make informed decisions about the true impact of digital technologies on electric power use and its impact on existing and future infrastructure.

Sensitive, Critical, and Non-Critical Equipment

It is well known that many digital end-use loads are susceptible to changes in the electric environment and that many of these loads are critical to specific business operations. However, digital equipment is not always more sensitive or more critical than non-digital equipment. There are many obvious examples.

One of the most sensitive electrical devices to voltage fluctuations and impulsive voltage surges is the standard incandescent light bulb. The bulb intensity or light output changes by a factor of three times the change in incoming voltage. Therefore, a 2% change in voltage will yield a 6% change in a typical incandescent lamp. The human eye-brain system easily detects 1-2% changes in light intensity and can, therefore, detect voltage of less than one percent. Lamp intensity changes may be irritating, but they are probably not critical to any process. On the other hand, when voltage surges occur, incandescent lamps are often first to fail. If the lamp happens to be in a stairwell or a hospital operating room, its function could be critical.

So incandescent lamps, while clearly not digital loads, are relatively sensitive and may be considered as critical, depending on how they are used. Other examples of very sensitive devices are the electromagnetic relays and sensors used in various mechanical processes. Factory assembly lines that require precise timing, robotic arm welders, automated paint spraying, relays controlling continuous processes, and many other non-digital systems are quite sensitive to voltage changes, and continuous voltage may also be critical to process operation.

Compare these sensitive non-digital loads to what we would consider a very digital load. An Internet workstation used for entertainment or to periodically send and receive email may be considered digital and yet not very critical equipment. A server used to control a continuous process such as ion sputtering in a semiconductor manufacturing plant may be critical to that operation; even a very momentary interruption in this process can result in hours of recovery and wasted materials. Criticality depends on how an appliance is used. Email may be time-critical in some cases; however, the ability to restart or revisit the email box another time is likely to be a sufficient backup.

What may be surprising about the more digital loads is just how rugged they can be. If we evaluate the sensitivity of the Internet workstation, we will find that it easily handles a few percent change in service voltage. In fact, the typical switch-mode power supply is able to handle voltage changes from half voltage to two times voltage for a few seconds. Surges of 4000 to 6000 volts are routinely tolerated when these surges are applied to the power supply terminals. So, it is possible to have digital loads that are not sensitive and non-digital loads that are very sensitive, while either may be critical to a particular process.

Several IEEE[34] standards have addressed measures of criticality and of critical tolerance levels. Definitions are provided for several measures of limits, tolerances, disturbance thresholds, and other aspects addressed in these standards:

Critical load. Devices and equipment whose failure to operate satisfactorily jeopardizes the health or safety of personnel, and/or results in loss of function, financial loss, or damage to property deemed critical by the user. [Source: IEEE Standard 1100]

Load susceptibility. The inability of a device, equipment, or system to perform without degradation in the presence of a power supply electrical disturbance. [Source: IEEE Standard 1100]

Load immunity (to a disturbance). The ability of a device, equipment, or system to perform without degradation in the presence of an electromagnetic disturbance. [Source: IEC[35]]

Note: Immunity refers to the opposite case of electromagnetic susceptibility. Susceptibility refers to the inability of the device to operate in the presence of an electromagnetic disturbance. See also: electromagnetic susceptibility.

Immunity level. The maximum level of a given power supply disturbance incident in a specified way on a particular device, equipment, or system, for which no degradation of operation occurs. [Source: IEC]

Electromagnetic disturbance. Any electromagnetic phenomena that may degrade the performance of a device, equipment, or system, or adversely affect living or inert matter. [Source: IEC]

Note: The term electromagnetic disturbance *is a very broad one, and can involve both conducted and radiated signals of an electromagnetic origin. Examples include radio frequency signals from broadcast facilities, radio frequency interference from devices with oscillators or digital clocking circuits (computers, digital recording and playback equipment, communications equipment), electric and magnetic fields from power lines, noise which is conducted along conductors or radiated due to corona discharge and partial breakdown, lightning strikes (which have strong fields associated with them), and many other phenomena. Another example is a cloud-to-ground lightning flash involving a massive electrical breakdown of the air dielectric between cloud and ground. This breakdown and the subsequent flow of charge produces strong localized time-changing electric and magnetic fields as well as somewhat weaker radiated electromagnetic waves with broad band characteristics stretching from a few kilohertz up to hundreds of megahertz. These fields can cause problems for power systems and devices, especially those within 1 km of the flash location.*

Power disturbance. Any deviation from the nominal value (or from some selected thresholds based on load tolerance) of the input AC power characteristics. [Source: IEEE Standard 1100]

Note: When monitoring electric power with many devices, thresholds are established to define what constitutes a power disturbance. Often, these thresholds are determined by the type of observed problems. For example, if a certain piece of equipment is failing, device-specific

[34] Institute of Electrical and Electronics Engineers, www.ieee.org
[35] International Electrotechnical Commission, www.iec.ch/home-e.htm

thresholds will be used (i.e. voltage limitations and noise limitations from the manufacturer) to establish the definition of a power disturbance.

Disturbance level. The level of a given steady state or dynamic electrical power supply disturbance, measured in a specified way. [Source: IEC]

Definition of Digital Energy Use?

In order to measure the evolution and variety of digital equipment types and applications, and to quantify digital energy use, digital equipment, digital processes, and digital businesses need to be better defined. With good definitions, trends and disruptions can be identified. Unambiguous classification will allow the development of systems and databases to better track changes and provide key indicators of the impact of a more digital society on the electric power system.

For the purposes of the CEIDS research activities related to digital equipment and this report, the electrical energy used by the digital economy, or “digital energy use,” is defined to encompass three distinct classes: 1) ***Digital Equipment and Devices***, 2) ***Digitally Controlled Processes***, and 3) ***Digitally-Enabled Enterprises***. The common thread between these three classes is their dependence on the microprocessor; in each class, the microprocessor uses electric energy to either support ITE (information technology equipment) or apply ITE to affect energy use in other processes or equipment.

The International Electrotechnical Commission (IEC) has nine product families used for categorizing equipment to determine electromagnetic compatibility. These are:

1. Household, commercial equipment (other than ITE)
2. Industrial equipment (other than ITE)
3. Information technology equipment (ITE)
4. Telecommunication equipment
5. Radio, TV, and similar equipment
6. Traffic and transportation equipment
7. Utilities equipment (electricity, gas, water)
8. Medical equipment
9. Measurement and test equipment

In North America, industries are categorized and tracked by a system developed in the U.S. Department of Commerce called Standard Industry Codes (SIC). The system uses a four-digit number to pinpoint industry type down to specific product or service levels. Just as IEC has nine product families, the SIC system starts with nine industry groups:

1. Agriculture, Forestry, Fishing (SIC Code Groups 01-09)
2. Mining (SIC Code Groups 10-14)
3. Construction (SIC Code Groups 15-17)
4. Manufacturing (SIC Code Groups 20-39)
5. Transportation and Public Utilities (SIC Code Groups 40-49)

6. Wholesale Trade (SIC Code Groups 50-51)
7. Retail Trade (SIC Code Groups 52-59)
8. Finance, Insurance, Real Estate (SIC Code Groups 60-67)
9. Services (SIC Code Groups 70-87)

Since four digits are assigned, the number of possible industry types in each group can be determined. For example, in Group 1, there is a possibility of 999 industry types; in Group 2, 500 types of mining; and Group 4 allows for 2000 types of manufacturing.

Classes of Digital Energy Use

Using the IEC product families together with the SIC industry types outlined above, the following sections give more detailed descriptions of each of the three classes that are proposed to represent all digital energy use:

Class 1: Digital Equipment and Devices (and Manufacture of Digital Equipment and Devices)

Class 1 is defined as any equipment, device, or system that has as its primary function packaging, processing, storing, accessing, monitoring, and measuring electronic data. It includes today's information technology equipment, such as:

- Digital computers and peripherals
- Servers for business networks
- Telephone systems
- Home computers
- Entertainment centers and other appliances
- Internet-enabling equipment
- Industrial process automation
- Programmable logic and numerical control

It also includes technologies just now emerging:

- Fault-tolerant computer architectures
- Wireless communications
- Interactive robotics
- Nanotechnology
- Neural computing
- Digital conferencing and entertainment
- Superconductivity

Typical applications in Class 1 include electronic-based office information technology (IT) equipment and commercial business and Internet data center (IDC) IT equipment. Also included is electronic-based equipment used in home offices, home entertainment centers, and electronic appliances. And, this class includes the application of IT in electronic automation equipment used in industrial plants and processes such as programmable logic control (PLC), machining numerical control, and microprocessor-based controllers.

This class of digital energy use can also be characterized as *digital processing equipment,* such as servers, computers, telecom, microprocessors, and their regulated DC power sources or switch-mode-power supplies. Also included are equipment and devices with embedded microprocessors and related software. The IEC product family that best describes digital processing equipment is *Information Technology Equipment*. Two other IEC-defined product families are also applicable: *Telecommunication Equipment* and *Radio, TV, and similar equipment*.

The National Electrical Code (NEC) defines information technology equipment (ITE) as a special category in Article 600. NEC Article 645 covers ITE as “equipment, power-supply wiring, equipment interconnecting wiring, and grounding of information technology equipment and systems, including terminal units, in an information technology equipment room.” The following comment and note are also included in the NEC definitions:

> “The term information technology equipment replaces other terms that describe computer-based business, personal, and industrial equipment. This terminology is also used by UL 1950, as well as international standards, as a more inclusive term for the equipment being addressed by Article 645. For further information, see Standard for the Protection of Electronic Computer/Data Processing Equipment, NFPA 75-1995.”

In some ways, describing IT loads may be easier than accounting for them. There is no universal system to track expected or actual energy use by digital equipment at the point of manufacture, point of sale, or point of use. Probably the best way to track digital energy use is to apply the existing system of Standard Industry Codes (SIC). The following codes are examples that could be applied to Class 1 of digital energy use. They include communications systems, IT equipment, and business services.

Transportation and Public Utilities (SIC Code Groups 40-49)

4800 - Communication
4812 - Radio/Telephone Communications
4813 - Telephone Communications, Except Radio
4822 - Telegraph and Other Communications
4832 - Radio Broadcasting Stations
4833 - Television Broadcasting Stations
4899 - Communication Services, NEC

Wholesale and Retail Trade (SIC Code Groups 50-59)

5045 - Computers, Peripherals, and Software
5084 - Industrial Machinery and Equipment
5731 - Radio, Television, and Electronics Stores

Class 1 also includes all equipment used in manufacturing digital electronic equipment, devices, and systems. This includes the manufacturing of digital-controller equipment, digital processing equipment, and related components and subassemblies. Because this class is specifically manufacturing, it is most easily accounted for by using the SIC manufacturing industry codes. The SIC codes for manufacturing that might be included are 3500 - Industrial and Commercial Machinery and Computer Equipment and 3600 - Electronic, Electrical Equipment, & Components.

Manufacturing (SIC Code Groups 20-39)

3500 - Industrial and Commercial Machinery and Computer Equipment
3571 - Electronic Computers
3572 - Computer Storage Devices
3575 - Computer Terminals
3577 - Computer Peripheral Equipment, NEC
3578 - Calculating and Accounting Equipment
3579 - Office Machines, NEC

3600 - Electronic, Electrical Equipment & Components

3651 - Household Audio & Video Equipment
3652 - Prerecorded Records and Tapes
3661 - Telephone/Telegraph Apparatus
3663 - Radio/TV Communication Equipment
3669 - Communications Equipment, NEC
3671 - Electron Tubes
3672 - Printed Circuit Boards
3674 - Semiconductors and Related Devices
3679 - Electronic Components, NEC
3695 - Magnetic and Optical Recording Media

The existing SIC system has limitations in distinguishing and accounting for a broad product family like IT and the services related to IT. Other methods of measuring the quantity and use of information technology equipment and related manufacture of this equipment are needed. One of these may be the new North American Industry Classification System (NAICS). Although in its early application stage, for the first time ever, North America is creating a product classification system that will be used to coordinate the collection, tabulation, and analysis of output and price data for products. One of the four general classes of products that is established in the NAICS is designated as *Information (sector 51).* See the section below, “Future Tracking for Digital Energy Use,” for a further discussion of NAICS.

Class 2: Digitally Controlled Processes

Class 2 is defined as process equipment, devices, and systems used to convert, control, and improve the process performance of other end-use equipment and devices. It includes many of today’s motor, lighting, or HVAC electronic controllers that save energy or increase process productivity. It is comprised of equipment used in digitally controlled processes such as:

- Medical electronics and automated surgery

- Digital information and security systems
- Electronic assembly and manufacturing
- Two-way communications and intelligence for all digital devices
- Continuous process manufacture, pharmaceuticals, food, etc.

An example of digitally controlled energy use would be an adjustable-speed drive (ASD) that controls a motor to provide speed control and/or energy savings. Another example is an electronic ballast that converts 60-Hz power to high frequency and improves the lumen per watt performance of fluorescent lamps. Yet another example is a power conditioner that will reshape, regulate, or suppress overvoltage and supplement missing voltage to better serve sensitive or critical equipment. All of these devices improve energy utilization by applying digital or information technology. This class of digital end-use may also be characterized as *smart utilization equipment.*

Accounting for this class of digital equipment may be very difficult as it is prevalent in many different industries, some not usually associated with the digital society. Because it is only a fraction of the equipment used in these industries, accounting for it requires some estimate of that percentage. How to determine the quantities sold of smart utilization equipment and its power requirements and trends is not clearly defined.

We know that smart devices are dispersed in practically every type of business and industry. The IEC product family categories provide one possible way to define families of products where these smart devices are most prevalent. Three of the nine IEC product families include equipment that fit this class definition: 1) Household, Commercial Equipment (other than ITE); 2) Industrial Equipment (other than ITE); and 3) Medical Equipment. The problem in using IEC product families is that they are not tracked in North America.

An alternative is to use SIC groups as a way to determine the numbers of these Class 2 devices at point of manufacture and point of sale. There are several problems in depending on the SIC to account for smart utilization equipment. One problem is that the total number of units manufactured in each SIC is not the same as the number that would be classified as smart devices, based on how they are applied. Another problem is that there are likely several categories of smart utilization equipment that are not tracked by SIC. Therefore, other tracking methods need to be developed to account for digitally controlled process energy use.

Some examples of smart utilization equipment that are included in the SIC are shown below:

Manufacturing (SIC Code Groups 20-39)

3500 - Industrial and Commercial Machinery and Computer Equipment
3541 - Machine Tools (Metal Cutting Type)
3542 - Machine Tools (Metal Forming Type)
3566 – Speed Changers, Drives, and Gears
3600 – Electronic, Electrical Equipment, and Components
3632 – Household Refrigerators/Freezers
3645 – Lighting Fixtures, Residential
3646 – Lighting Fixtures, Commercial
3648 – Lighting Equipment, NEC
3823 - Process Control Instruments

3825 - Instruments To Measure Electricity
3826 - Analytical Instruments
3827 - Optical Instruments and Lenses
3829 - Measuring and Controlling Devices
3841 - Surgical and Medical Instruments
3842 - Surgical Appliances and Supplies
3843 - Dental Equipment and Supplies
3844 - X-Ray Apparatus and Tubes
3845 - Electromedical Equipment

Wholesale and Retail Trade (SIC Code Groups 50-59)

5047 – Medical and Hospital Equipment
5075 – Warm Air Heating and Air Conditioning
5078 – Refrigeration Equipment and Supplies

Class 3: Digitally Enabled Enterprises

Class 3 is defined as the new business enterprises that exist because of the convergence of electronics, information technology, communications, and the Internet. Digitally enabled enterprises include existing businesses that are being radically transformed by these technologies: today's e-supporting businesses, software developers, credit card and other financial companies, distributors, suppliers, service organizations, and other enterprises comprising all future B2C and B2B businesses. Class 3 is the measure of heightened productivity and profitability through:

- Full enterprise-wide data and network communications
- Real-time inventory, process, monitoring, and quality control

Class 3 also includes minimization of all waste in modern, efficient businesses that can be attributed to digital equipment and digital society processes. This is a class of digital society energy use that is not easily measured. However, it is growing in importance and it needs to be better defined. New methods are needed for measurements of energy use and other important dimensions of this significant element of the U.S. and world economy. Some of the existing services categories of SIC may be applicable, as follows:

Services (SIC Code Groups 70-87)

4841 - Cable and Other Pay Television Services
5734 - Computer and Software Stores
6100 - Nondepository Credit Institutions Services
6153 - Short-Term Business Credit Institutions
6159 - Miscellaneous Business Credit Institutions
7300 - Business Services
7371 - Custom Computer Programming Services
7372 - Prepackaged Software
7373 - Computer Integrated Systems Design
7374 - Data Processing Services
7375 - Information Retrieval Services

7376 - Computer Facilities Management
7377 - Computer Rental and Leasing
7378 - Computer Maintenance and Repair
7379 - Computer Related Services, NEC

Future Framework for Tracking Digital Energy Use

Using SIC categories as outlined above for determining energy use in the digital society may be improved upon in the near future. The North American Industry Classification System (NAICS) is replacing the U.S. Standard Industrial Classification (SIC) system. NAICS will reshape the way we view our changing economy. NAICS was developed jointly by the U.S., Canada, and Mexico to provide new comparability in statistics about business activity across North America

NAICS industries are identified by a six-digit code, in contrast to the four-digit SIC code. The longer code accommodates the larger number of sectors and allows more flexibility in designating subsectors. It also provides for additional detail not necessarily appropriate for all three NAICS countries. The international NAICS agreement fixes only the first five digits of the code. The sixth digit, where used, identifies subdivisions of NAICS industries that accommodate user needs in individual countries. Thus, six-digit U.S. codes may differ from counterparts in Canada or Mexico, but at the five-digit level they are standardized.

Another development that will facilitate tracking digital energy use is forthcoming in conjunction with the changeover to NAICS. The Economic Classification and Policy Committee (ECPC) of the U.S. Office of Management and the Budget is currently developing a comprehensive classification system for the products produced by the spectrum of U.S. industries that have recently been defined and classified under NAICS.

This new product classification system will be used to coordinate the collection, tabulation, and analysis of output and price data for products. The project is being implemented in two phases: Phase 1 - products of selected service sectors, and Phase 2 - products of all goods and services sectors. The Discussion Paper, *A Bridge Between NAICS and SIC*, provides 1997 Economic Census data used in Phase 1 of the ECPC initiative.

Phase 1 of the ECPC initiative is an exploratory effort that focuses on the identification and classification of the products sold by service industries in four selected NAICS service sectors:

1. Information (Sector 51).
2. Finance and insurance (Sector 52) except insurance (Sub-sector 524).
3. Professional, scientific, and technical services (Sector 54).
4. Administrative and support, waste management, and remediation services (Sector 56).

Phase 2 will develop a comprehensive list of products that encompasses both goods and services products alike and a demand-side/market-orientated classification framework for grouping and aggregating these products. The new product classifications under NAICS will eventually be cross-referenced with the older International Electrotechnical Commission (IEC) product families. The IEC product family that best describes digital end-use equipment is *Information Technology* (IT). The general industry class that begins to address e-business is designated as *Information*, sector 51 in NAICS.

Need for Standard Measurement Protocol to Determine Population, Usage, and Demand

The IEC has established standards related to the electromagnetic compatibility (EMC) of end-use equipment and electric power systems. In this system of standards, there are three categories: 1) Basic, 2) Generic, and 3) Product Family Standards. The Basic EMC standards give fundamental conditions or rules concerning terminology, phenomena, environments, and compatibility levels. The Generic EMC Standards are related to specific environments with minimum requirements or test procedures concerning emission and immunity limits. Finally, the Product Family EMC Standards define specific EMC requirements for particular products.

The Product Family standards have precedence over Generic Standards. They are to be coordinated with the relevant Generic EMC Standards and should not include detailed measurement and test methods. They are intended to refer to the Basic EMC standards to provide a consistent treatment of product compatibility with allowances for the specific requirements of each product family. They can take the form of separate publications or clauses in more general Product Family Standards and should indicate relevant installation and operation conditions.

A similar measurement protocol could be applied to determine how many digital devices and processes are in the digital economy and their electrical energy usage, and thus the demand on the electric power system. Such a system of standards, in conjunction with the NAICS product classification, could be the key to defining digital applications and quantifying present and future trends in digital energy use.

3

SUPPORTING THE DIGITAL SOCIETY: A MEASURE OF VALUE

A Multidimensional Challenge

This year, according to the *New York Times*, approximately 150 million computers will be sold in the U.S., and another 3 billion embedded CPUs are sold each year.[36] These staggering numbers provide one means of measuring the magnitude of the digital economy. But how do we truly quantify the significance of the digital economy, and how much of our nation's electrical resources are needed to support it? These are but two of the many concerns that face electrical service providers as they produce and distribute power for today's digital society.

And, will the answers to these questions provide a complete and comprehensive picture? Probably not. While the U.S. Department of Commerce is concerned with GNP and productivity associated with the digital economy, electric service providers are primarily concerned with electrical consumption, the power required by increasing digital loads, the nonlinear implications on electrical infrastructure, and having the appropriate electrical infrastructure necessary to support such loads. So what is the appropriate measure of value of the digital society?

Based on the premise that utilities want to know the energy consumption (load) of the digital economy, the only measurements needed would be power requirements (kW) or electrical consumption (kWh). The load is indeed of interest for utilities, especially if it's changing and unpredictable. On the other hand, focusing on load alone is a very limited perspective. For most players in the digital economy, energy consumption is a relatively insignificant factor compared to the sales opportunities, elegant simplicities of retailing, and dollar-volume potential inherent in e-business. The prospects of these businesses can be impacted by many other factors beyond electric power supply. And, as important as e-business is and may become, even without a single credit card transaction there are still enormous societal benefits and productivity gains from Internet communications and information sharing. Take away the Internet and e-business, and we still have PLCs, PCs, and embedded microprocessors in every business sector that are improving the performance of practically every process and system imaginable.

Clearly, the digital society is multidimensional—one set of indices or measures is simply inadequate and insufficient to project an accurate picture of the whole. One dimension of particular interest to the U.S. Department of Energy's (DOE) Energy Information Agency (EIA) was to identify the energy use of the digital society. The EIA commissioned Lawrence Berkley National Laboratory (LBNL) to count up the total number of servers and routers and estimate absolute and relative energy consumptions. LBNL's work represents a valuable and necessary

[36] Philip J. Koopman, Jr., *Embedded System Design Issues: The Rest of the Story*, preprint of paper published in Proceedings of the International Conference on Computer Design (ICCD '96).

first cut at one of the metrics needed to quantify the digital society. However, it is not a complete appraisal.

Consider, for instance, the new-generation server that completes 1,000 times more “information processes” per watt, or the router that sends 10 times the message units with less than one-half the watts consumed. On a traditional energy-consumption basis, a measure of these more efficient digital devices would show less consumption—would that therefore imply that the digital economy is somehow less digital, or at least not as significant? A similar argument might be applied to the application of a digitally controlled ASD. The ASD reduces consumption; however, it’s the conservation, not the consumption, that should be a measure of the ASD’s value. Microprocessors may only slightly impact energy consumption, yet greatly increase productivity; here it’s the productivity that we need to measure, not the consumption.

We have several metrics or indices that we should be measuring, like productivity, efficiency, and the enabling aspects of the digital economy’s equipment and processes. However, many of these needed indices or metrics may not be readily available or available at all. There is a need to rethink what are the appropriate measures of value for the digital economy and to engage industry in developing suitable indices. From there, more specific energy performance metrics—message-units transmitted/watt, megabits stored or retrieved/watt, information processes/watt—can be analyzed.

Some of the dimensions that, along with appropriate indices, might more accurately demonstrate the complete value of the digital society for all players include:

Internet

- Number of subscribers
- Coverage as percent of population or number of business
- Time online
- Number of messages transmitted
- Gigabits of available information: images, documents, movies, music

The electric energy use of the Internet infrastructure is Class 1: Digital Equipment and Devices (see Chapter 2). Information is available from LBNL, Above Net, and other sources.

E-business

- Number of transactions
- Dollar volume
- Number of companies and available products
- Number of providers and available services

The electric energy use of the e-business and related infrastructure is Class 3: Digitally Enabled Enterprises (see Chapter 2), which rely on the Internet, IT processing, data storage, and telecom equipment.

Industrial Process Control

- Penetration numbers (or watts) by industry type (SIC)
- Productivity impact by industry type (SIC)
- Efficiency impact by process or industry type

The percent of plant energy use from load equipment related to digital processes is Class 2: Digitally Controlled Processes (See Chapter 2), which derive energy savings or productivity enhancement (based on SIC category or point-of-use).

Information Technology (in Offices, Factories, and Residences)

- Number of office complexes
- Square foot of commercial office complex
- Number of factory computer centers
- Number of households with PCs
- Number of home offices

The percent of energy use from loads related to digital information processing, including packaging, processing, storing, accessing, monitoring, and measuring electronic data, is Class 1: Digital Equipment and Devices.

Energy Star and Adaptive Appliances

- Number of energy-managed residential appliances, such as the "smart" refrigerator, high-efficiency air conditioner, occupant/environment-adaptive lighting, and other services
- Number of energy-managed commercial appliances, such as smart elevators, revolving doors and escalators, high-efficiency space conditioning, occupant/environment-adaptive lighting, and other services

The energy use from load equipment related to these adaptive energy-efficient appliances and processes is Class 2: Digitally Controlled Processes, which derive energy savings or productivity enhancement (based on appliance or functional category such as cooling, people moving, food service, and so on at the point of use).

Media and Entertainment

- Number of cable connections or cable/telephone office communication systems
- Number of cable connections or cable/telephone home entertainment systems

The percent of energy use from loads related to digital processes related to information, telecommunication, and media-related appliances is Class 1: Digital Equipment and Devices.

Digital Support Industries

- Software categories and related business infrastructures

- Computer and Internet support products and related business infrastructures

The electric energy use of these support industries is Category 3: Digitally Enabled Enterprises, which rely on Internet, IT processing, data storage, and telecom equipment.

Using Available Data as Baseline

Although much of the data from these dimensions and indices is either non-existent or not readily available, it is important to start the process of providing a tangible measure of the significance of the digital economy by establishing a baseline. Therefore, based on the three distinct classes of digital energy use defined in Chapter 2, this chapter will provide information and data that will help to show but a glimpse of the significance of the digital economy, from its impact on the GNP to electrical consumption of digital loads. Data readily available from the Department of Commerce, Department of Energy, Lawrence Berkeley National Laboratory, and other sources were used extensively in compiling this baseline.

A macro approach can be useful to assess the size and evaluate the significance of the digital economy. The U.S. Census Bureau's Economic Census is a good starting point because it compiles data that includes the number and type of business establishments, plus their annual revenue, number of employees, and payroll. For compiling the baseline of energy use in the digital economy, the Census Bureau data is used in conjunction with the U.S. Department of Commerce's Standard Industry Code (SIC) categories. As discussed in the previous chapter, however, the existing SIC system has certain limitations—for example, in distinguishing and accounting for a broad product family like IT and IT-related services—and all devices within each of the categories should not be classified as digital. Nonetheless, the SIC and Census Bureau information can still provide a macro perspective of the overall value and magnitude for each of the three main classes of digital devices, processes, and enterprise.

Since finer metrics are needed to move beyond this baseline; a total assessment may ultimately depend on the industry products and services codes of the new North American Industry Classification System (NAICS). The information presented in Appendix A for Class 1, although formatted based on SIC codes, also displays the corresponding NAICS codes and the percent completion of transition between the two systems.

Class 1: Digital Equipment and Devices (and the Manufacture of Digital Equipment and Devices)

Class 1 is defined as any equipment, device, or system that has as its primary function packaging, processing, storing, accessing, monitoring, and measuring electronic data. It includes today's information technology equipment, such as computers and peripherals, and servers, as well as telecommunications systems, audio and video devices, and all equipment used in manufacturing digital equipment and devices.

Appendix A provides basic data for the SIC categories previously defined under Class 1: Digital Equipment and Devices.

Total U.S. Electric Consumption Trends

Although the U.S. Census Bureau information helps to provide a macro approach to assess the impact of digital equipment, processes, and enterprises on the electric power system, many electric service providers still want to know just how much power is required and how much energy is consumed by the digital economy so that they can have the resources available to meet these requirements.

Simply “gold-plating” the present delivery system would not be an economically or technically feasible way to provide the level of reliability, quality, and availability required by microprocessors and other digital devices, nor will it address the issue of security: the vulnerability of the system to damage from natural disasters or terrorist activity. Meeting the energy requirements of an increasingly digital society will require applying a combination of advanced technologies—from generating devices (including conventional power plants, fuel cells, and microturbines) to interface devices to end-use equipment and circuit boards.

To ascertain exactly what resources will be necessary to meet the energy requirements of the digital society, the next step is to analyze just how much energy digital devices use. In so doing, it is first important to quantify the total electrical consumption within the U.S. across all three major sectors – residential, commercial, and industrial (see Figure 3-1).

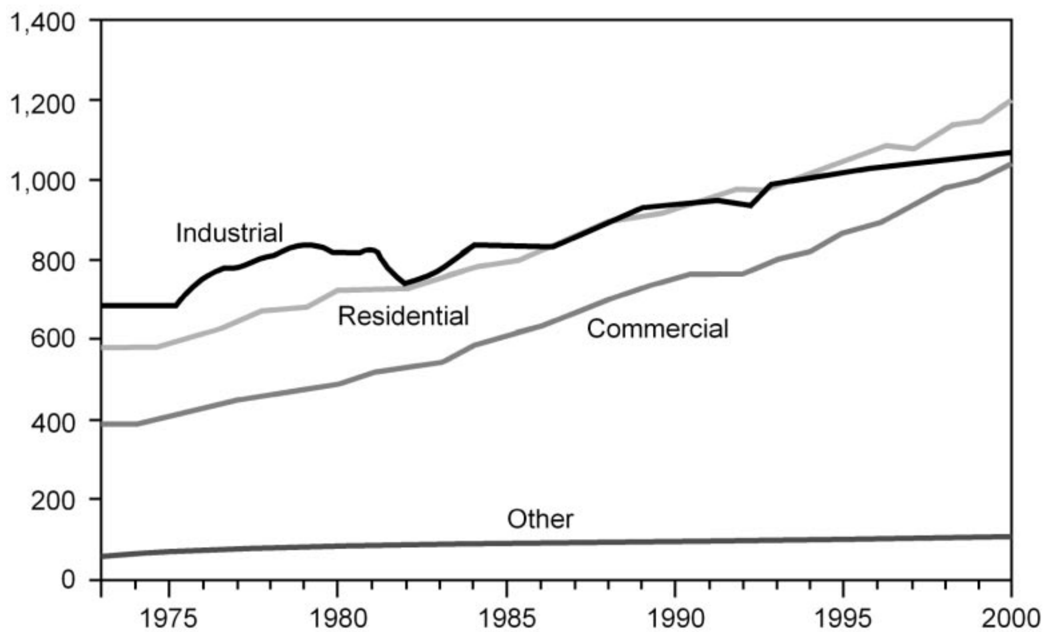

Figure 3-1
Electric Utility Retail Sales by Sector (Source: EIA)

There has been a great deal of concern raised over the last several years that digital loads are increasing at a rate so high that the increase will lead to an energy shortage (http://www.fossilfuels.org/Electric/internet.htm). However, the U.S. Department of Energy’s Energy Information Administration (EIA) data for electric utility sales over the past 25 years and a comparison of this data with recent trends in electricity demand growth by sector indicates that there is no direct correlation or comparable percentage increase in electrical consumption due to an increase in digital loads (see Figure 3-2 and Figure 3-3).

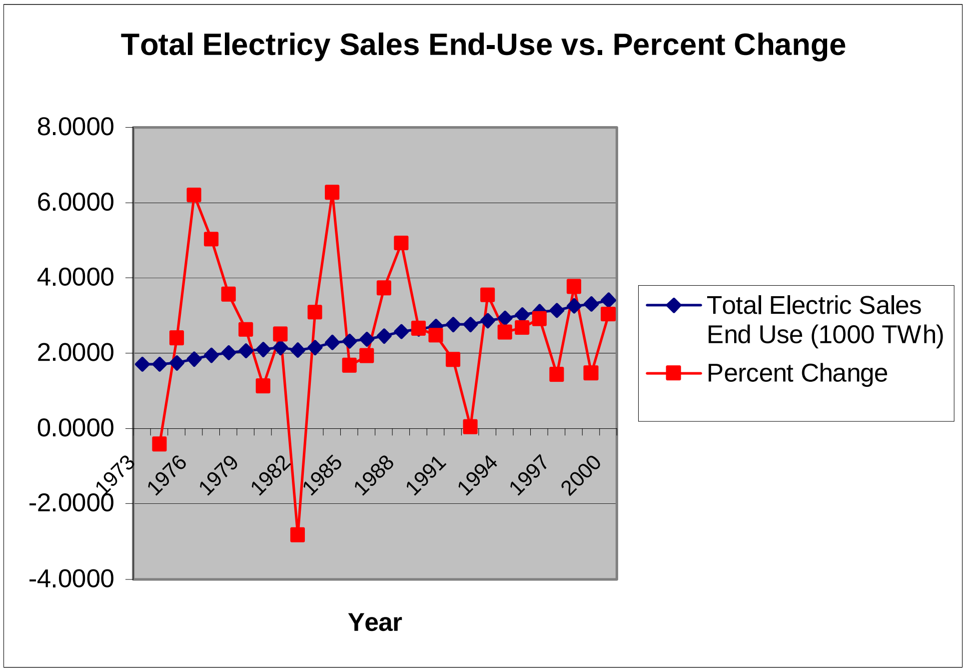

Figure 3-2
History of 25 Years of Electricity Sales End-Use Versus Percent Change

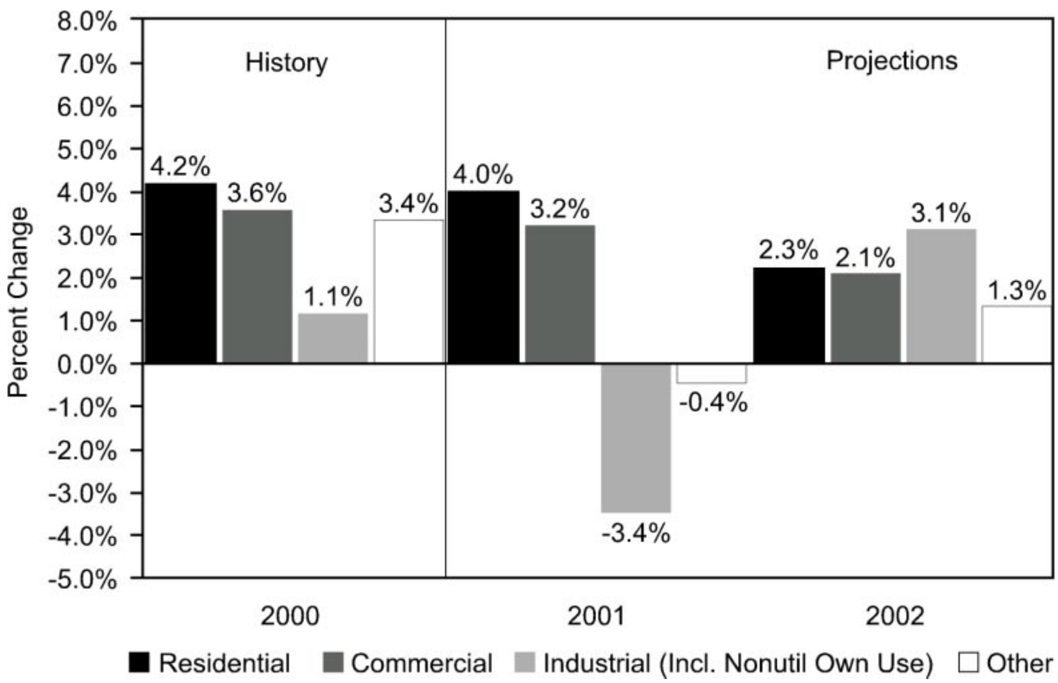

Figure 3-3
U.S. Electricity Demand Growth by Sector

EIA has provided a short-term outlook as well that is consistent with these recent growth trends, with the exception of the industrial sector (U.S. Energy Information Administration, Short-Term Energy Outlook - March 2002, March 6, 2002, http://www.eia.doe.gov/emeu/steo/pub/contents.html):

"Electricity demand in the industrial sector in 2001 was adversely affected by the overall economic slowdown, particularly as illustrated by falling industrial output. In 2002, growth in industrial demand for electricity (including estimated net industrial own-use generation) is expected to grow by about 1.4 percent in contrast to the estimated 8.0 percent contraction seen in 2001. This category of demand growth is expected to exhibit (approximately normal) growth of 3.3 percent in 2003 as the economic recovery proceeds. In 2003, growth in residential demand for electricity is expected to be 3.5 percent, due mainly to assumptions of normal weather. This winter, total electricity demand growth is expected to be negative (down 3.9 percent) compared with last winter's demand growth of 4.7 percent due to the weaker industrial economy and the relatively warmer weather."

Table 3-1
Electric Utility Retail Sales 1999 and 2000: Percent Change (Source: Energy Information Administration Monthly Review July 2001)

	1999	2000	Percent Change
Electricity End Use (million kilowatt-hours)	3,312,087	3,412,766	3.04
Residential	1,144,923	1,193,380	4.23
Commercial	1,001,996	1,037,936	3.59
Industrial	1,058,217	1,070,827	1.19
Other	106,952	110,622	3.43

In comparison, Primen estimates that total electricity use in the residential, commercial, and manufacturing sectors in 2001 is 3,392 trillion watt-hours (TWh). Of this, Primen estimates that 391 TWh, or 12%, are from digital equipment and components. The following tables and figures provide details.

Table 3-2
Electricity use in 2001 (TWh/year)

Sector	Total	Digital	Non-Digital	% Digital
Residential	1,183	150	1,034	13%
Commercial	1,142	148	994	13%
Industrial	1,067	93	974	9%
Total	3,392	391	3,001	12%

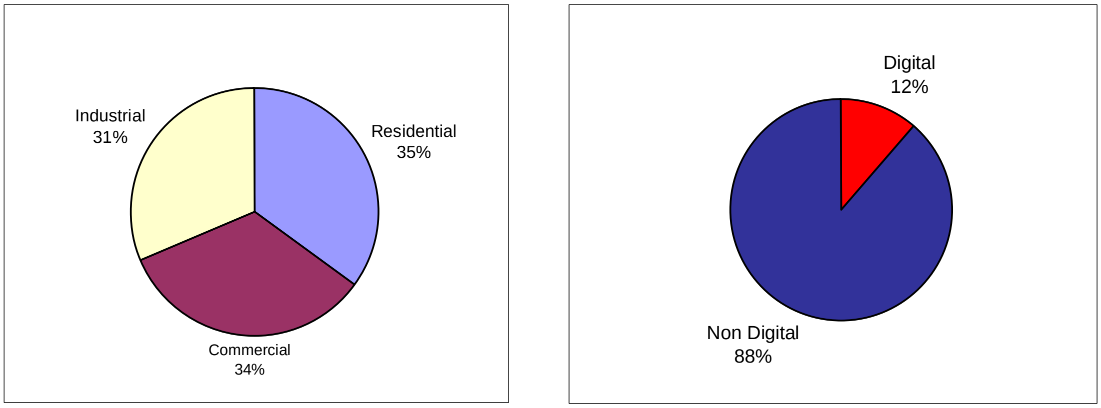

Figure 3-4
Distribution of Electricity Use in Residential, Commercial, and Industrial Sectors, and Distribution by Digital/Non Digital

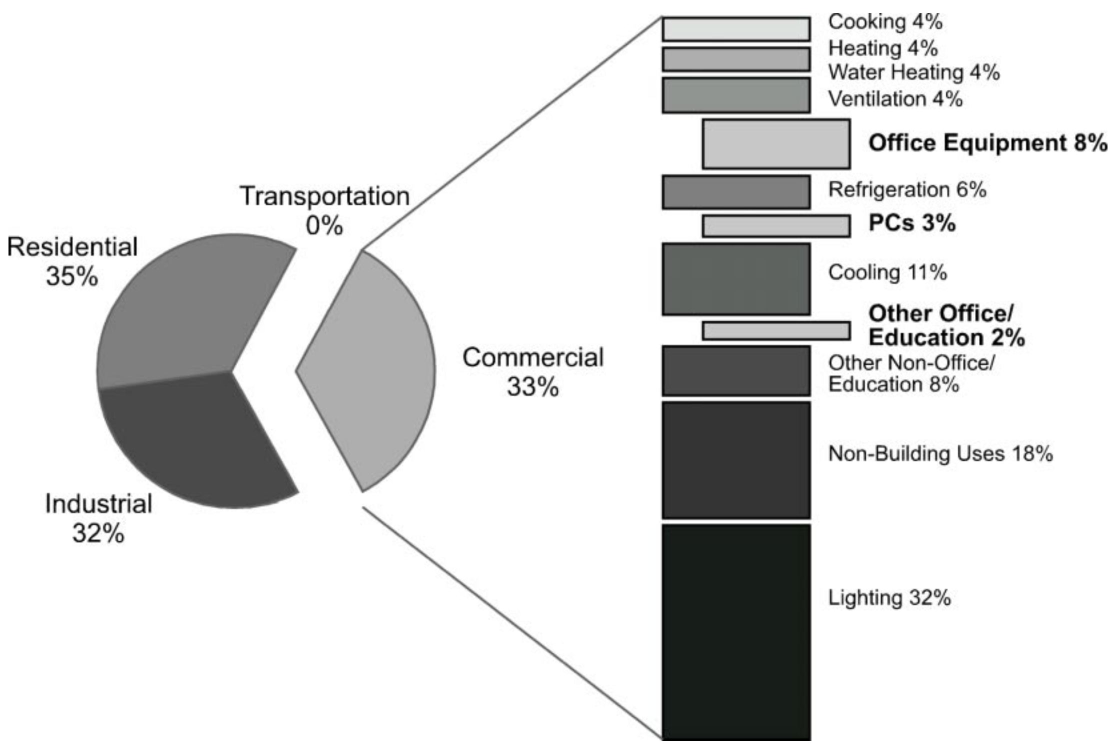

Figure 3-5
Commercial Sector Electricity Consumption

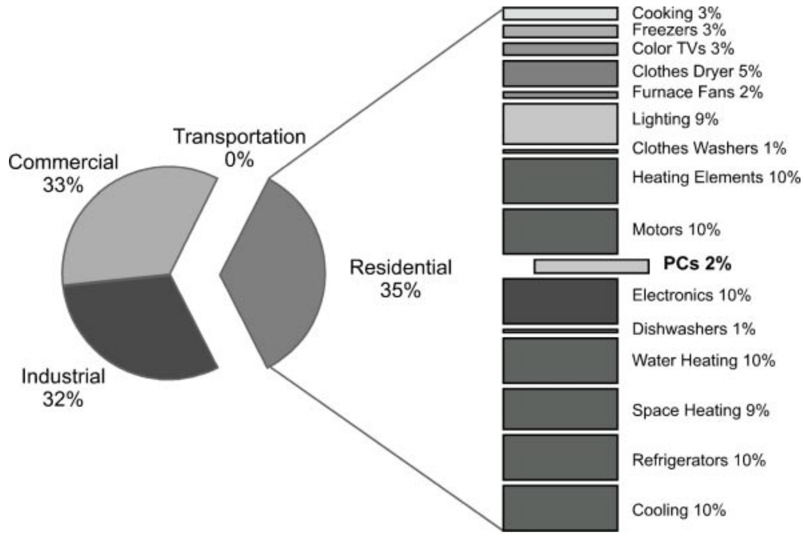

Figure 3-6
Residential Sector Electrical Consumption

Table 3-3
Annual Energy Use for Office Equipment in 1999 (Source: LBNL[37])

Equipment Type	Residential	Commercial	Industrial	Total
Portable Computer	0.14	0.13	0.02	0.29
Desktop Computer	2.67	10.21	1.46	14.34
Server	0	1.60	0.23	1.83
Minicomputer	0	8.86	2.95	11.81
Mainframe	0	5.62	0.63	6.25
Terminal	0	1.83	0.61	2.44
Display	3.13	9.82	1.40	14.35
Laser Printer	0.10	5.36	0.77	6.23
Inkjet/Dot Printer	1.10	1.56	0.22	2.88
Copier	1.10	5.71	0.82	7.63
Fax	0.44	2.26	0.32	3.02
Totals	8.67	52.95	9.42	71.04

[37] Kaoru Kawamoto, Jonathan Koomey, Bruce Nordman, Richard Brown, Mary Ann Piette, Michael Ting, and Alan K. Meier, "Electricity Used by Office Equipment and Network Equipment in the U.S.: Detailed Report and Appendices," LBNL-45917, Lawrence Berkeley Natl Lab, CA, Sept. 2001, **http://enduse.lbl.gov/Info/Pubs.html**.

Table 3-4
Best Estimate of Annual Energy Use by Network Equipment in 1999 (TWh/Year) (Source: LBNL[38])

	Equipment Type	Annual Energy Use
WAN	Router Switch	0.05 0.24
LAN	Router Switch Access Drive Hub	0.68 1.31 0.29 0.65
Total		3.22

Table 3-5
Electricity Used by Office Equipment Type and Building 2000[39]

	Offices	Retail	Groceries	Schools	Hos-pitals	Hotels	Misc.	Rest-aurants	Ware-houses	Totals
PCs	7.2	0.9	0.0	1.0	0.1	0.3	0.6	0.1	0.1	10.3
Monitors	7.2	1.0	0.0	1.7	0.3	0.4	0.6	0.1	0.5	11.6
Laser Printers	2.9	0.5	0.0	0.4	0.3	0.1	0.5	0.0	0.5	5.4
Serial Printers	0.9	0.1	0.0	0.1	0.1	0.0	0.2	0.0	0.1	1.6
Copiers	2.2	0.8	0.0	0.6	0.2	0.0	1.3	0.0	0.6	5.7
Faxes	1.2	0.2	0.0	0.2	0.1	0.0	0.2	0.0	0.4	2.3
POS Terminals	0.2	3.9	0.3	0.0	0.1	0.1	0.2	0.6	0.0	5.4
Mainframes	3.0	0.6	0.0	0.7	0.1	0.1	0.2	0.0	0.9	5.6
Mini-computers	4.6	1.5	0.0	1.6	0.2	0.2	0.5	0.0	1.9	10.5
Totals	29.4	9.5	0.4	6.4	1.5	1.2	4.1	0.8	5.0	58.3

[38] Kaoru Kawamoto, Jonathan Koomey, Bruce Nordman, Richard Brown, Mary Ann Piette, Michael Ting, and Alan K. Meier, "Electricity Used by Office Equipment and Network Equipment in the U.S.: Detailed Report and Appendices," LBNL-45917, Lawrence Berkeley Natl Lab, CA, Sept. 2001, **http://enduse.lbl.gov/Info/Pubs.html**.

[39] "Electricity Technology Roadmap: 1999 Summary and Synthesis," EPRI: Palo Alto, 1999.

Many of the estimates regarding digital load electrical consumption are somewhat erroneous due primarily to the fact that actual usage and nameplate ratings differ, at times greatly. The following chart (see Figure 3-7) reveals nameplate ratings for servers versus actual electrical consumption measured by engineers and technicians. The nameplate is often higher by a factor of 1.5 to 4 times greater.

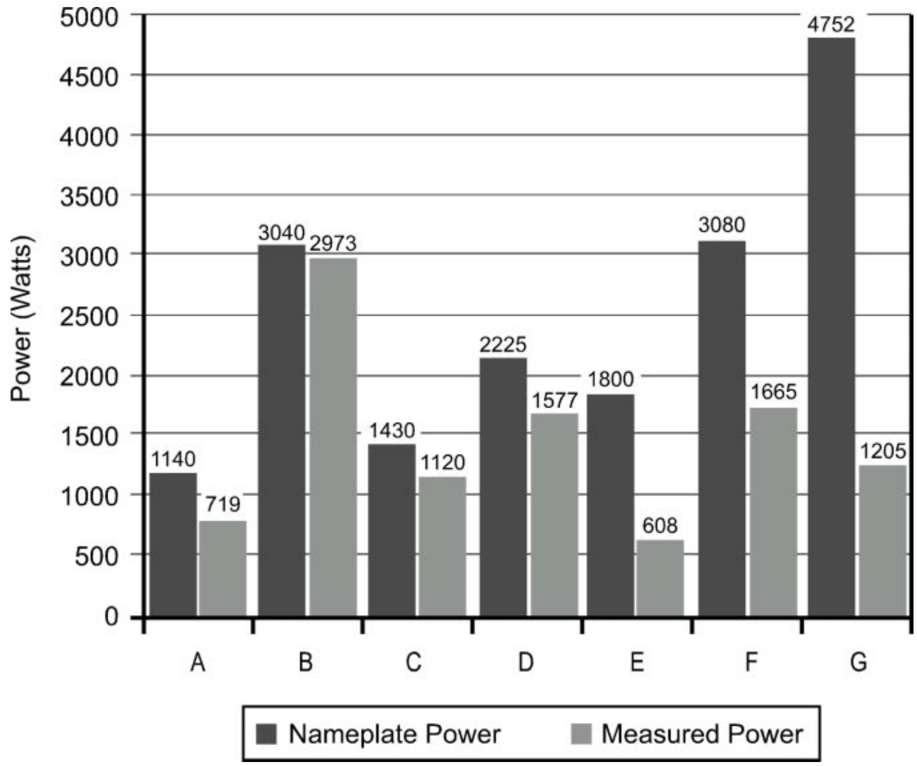

Figure 3-7
Nameplate versus Actual Power Requirements and Electrical Usage for Various Internet and End-User Server Equipment

In addition, many companies are striving to develop newer technologies with higher efficiencies, as noted in a recent *Financial Times News* article (April 23, 2001).

Residential Sector

Primen estimates that residential electricity use in 2001 is 1,183 TWh. They project electricity use to increase by 23% over the next 10 years to 1,454 TWh.

Table 3-6 presents a comparison of the Primen forecast results compared with GTI and AEO. While the starting values in 2001 are different, the average rate of change is similar over the ten-year period.

Table 3-6
Residential Electricity Forecast Comparison

Source	2000 TWh	2001 TWh	2010 TWh	2011 TWh	Avg. Annual Change
Primen		1,183		1,454	1.62%
GTI 2000	1,175		1,438		1.68%
AEO		1,433		1,703	1.66%

Table 3-7 provides a breakdown of residential electricity use by end use. It also identifies the fraction of electricity use from digital equipment and components. Overall, digital equipment and components account for 120 TWh or 11% of total residential electricity use in 2001.

Table 3-7
Residential Electricity Use in 2001 (TWh)

End Use	Total	Digital	Non Digital	% Digital	% of Digital Total
Home Electronics	76	59	17	78%	49%
Office Equipment	33	33	-	100%	28%
Miscellaneous	221	11	210	5%	9%
Lighting	94	9	85	10%	8%
HVAC	326	3	323	1%	3%
Appliances	373	4	369	1%	3%
Totals	1,124	120	1,004	11%	100%

Table 3-8 presents similar information for 2011. By 2011, Primen projects that residential electricity use will increase by 29% to 1,454 TWh. Primen projects that by 2011, the electricity use by digital equipment and components will increase by 92% to 288 TWh, which represents 20% of total residential electricity use. Table 3-8 provides a breakdown of electricity use by end use.

Table 3-8
Residential Electricity Use in 2011 (TWh)

End Use	Total	Digital	Non Digital	% Digital	% of Digital Total
Home electronics	103	98	5	95%	34%

Office equipment	71	71	-	100%	25%
Miscellaneous	312	60	252	19%	21%
Lighting	136	28	108	20%	10%
HVAC	444	17	427	4%	6%
Appliances	390	15	375	4%	5%
Total	1,454	288	1,167	20%	100%

End-Use Discussion

In this section, Primen describes assumptions about the end uses that contribute significantly to residential digital electricity use.

Home Electronics

Home electronics consists of TVs, VCRs, DVDs, component stereos, compact stereos, portable stereos, clock radios, analog cable boxes, digital cable boxes, satellite receivers, game consoles, answering devices, cordless phones, answering devices, and chargers. Primen estimates that home electronics used 76 TWh or 7% of total residential electric sales in 2001. Primen projects that this will increase by 36% to 103 TWh in 2011.

The digital load contribution for this end use is substantial. Almost the entire load of these devices can be attributed to digital components. As analog and partially analog TVs and cable boxes are replaced with digital equipment, the digital load will further increase. In 2001, Primen estimates that 78% of home electronics electricity use is attributed to digital components, and that this will increase to 95% by 2011. This corresponds to 59 TWh in 2001 and 98 TWh in 2011.

Office Equipment

Office equipment consists of computers, printers, fax machines, and copiers. All of this is defined as digital. In 2001, office equipment used 33 TWh (3%) of total residential electric sales. By 2011, Primen estimates that this will more than double to 71 TWh or 5% of total electricity use.

Miscellaneous Plug Loads

This end use consists of all plug loads not elsewhere classified. It includes pool pumps, garage door openers, hair dryers, and power tools. In 2001, it accounted for 221 TWh or 20% of total residential electric sales. Primen projects that it will grow by 41% to 312 TWh by 2011.

The digital load contribution for this end use is relatively significant. As technologies evolve, electronic controls, displays, sensors, and other components of these loads will become more common. Primen estimates that 5% of the total appliance load had a digital component in 2001 and that this will increase to 19% in 2011. This corresponds to 11 TWh in 2001, and 60 TWh in 2011.

Lighting

Lighting includes fluorescent, compact fluorescent, incandescent, spot, and other technologies. In 2001, Primen estimates that lighting accounted for 94 TWh of total residential electric sales and that it will increase by 45% to 136 TWh in 2011.

The digital portion of lighting includes electronic ballasts in fluorescent lighting, occupancy and motion sensors, and compact fluorescents. Primen estimates that 10% of the lighting use in 2001 is from digital components, and that this will increase to 20% in 2011. This stems from the increased use of fluorescent fixtures and the replacement of magnetic ballasts with electronic ballasts. Primen estimates that digital energy use is 9 TWh in 2001 and that it will more than triple to 28 TWh in 2011.

HVAC

HVAC includes heating, cooling, and ventilation. In 2001, it consisted of 326 TWh or 29% of total residential electric sales. Primen projects that HVAC use will grow to 444 TWh in 2011.

The digital components include electronic thermostats, digitally controlled equipment (dampers, fans, etc.), and displays. As HVAC technologies evolve, digital interface and control will increase (with varying rates, depending on the system). However, it will likely remain a relatively small component to the total load. Primen estimates that 1% of the total HVAC load results from digital components in 2001 and that this will grow to 4% in 2011. This corresponds to 3 TWh in 2001 and 17 TWh in 2011.

Appliances

The appliance category includes major household appliances, including cooking equipment (including microwaves), refrigerators, freezers, dishwashers, clothes washers, clothes dryers, and domestic hot water heaters. In 2001, Primen estimates that appliances used 373 TWh of total residential electric sales, and that their use will grow only slightly to 390TWh.

Although most individual appliances have a digital component for displays and controls, the digital load contribution for this end use is minimal. As digital technologies evolve, the appliances with a digital component will approach 100%—for instance, “Internet-style” refrigerators are being introduced that display recipes and communicate with other appliances. However, the majority of the appliances will likely remain largely unchanged. Primen estimates - that 1% of the total appliance load is from the digital components in 2001 and that this will grow to 4% in 2011. This corresponds to 4 TWh in 2001 and 15 TWh in 2011.

Table 3-9
Energy Use of U.S. Consumer Electronics in 20th Century (Source: LBNL)

Product	Units in 1999 (M)	Standby Energy (TWh/yr)	Idle Energy (TWh/yr)	Charge Energy (TWh/yr)	Active Energy (TWh/yr)	Total Product Energy Use (TWh/yr)	Share of U.S. Residential Electricity Use in 1999 (%)
Analog TV	220	7.3			23.5	30.8	2.7

Digital TV	1	0.1			0.3	0.3	0.0
VCR	130	5.2	3.7		0.7	9.6	0.9
Component Stereo	75	1.3	4.6		5.5	11.4	1.0
Compact Stereo	50	3.1	1.6		0.9	5.6	0.5
Portable Stereo	70	0.6	0.4		0.2	1.2	0.1
Clock Radio	130	1.9			0.0	1.9	0.2
Analog Cable Box	40	2.9			0.9	3.8	0.3
Digital Cable Box	3	0.5			0.1	0.6	0.1
Satellite Box	13	1.5			0.4	2.0	0.2
Game Console	54	0.4	0.0		0.8	1.2	0.1
Answering Device	77	2.1			0.0	2.1	0.2
Cordless Phone	87	0.7		1.6	0.1	2.5	0.2
Cordless Answering Device	35	0.1		0.7	0.0	0.8	0.1
Cell Phone	70	0.5		0.2	0.0	0.6	0.1
Computer	61	0.4	21.2		3.3	24.9	2.2
Printer	74	0.9	3.9		2.3	7.2	0.6
Fax/Copier	10	0.0	2.7		0.1	2.8	0.2
Peripheral	186	1.9	0.7		0.5	3.2	0.3
Totals		32	39	2.6	40	113	10

Commercial Sector

Primen estimates that commercial electricity use in 2001 is 1,142 TWh. They project electricity use to increase by 24% over the next 10 years to 1,415 TWh. Table 3-10 presents a comparison of Primen's forecast results compared with similar forecasts by GTI and AEO. While the starting values in 2001 are different, the average rate of change is similar over the ten-year period.

Table 3-10
Commercial Energy Forecast Comparison

Source	2000 TWh	2001 TWh	2010 TWh	2011 TWh	Avg. Annual Change
Primen		1,142		1,415	2.4%
GTI 2000	1,297		1,597		2.3%
AEO	1,331		1,716		2.9%

Table 3-11 provides a breakdown of electricity use by digital segments and by end uses in non-digital segments. It also identifies the fraction of electricity use from that comes from digital equipment and components. Overall, digital equipment and components account for 148 TWh or 13% of total commercial electricity use in 2001.

Table 3-12 presents similar information for 2011. By 2011, Primen projects that electricity use will increase by 24% to 1,415 TWh. Primen projects that the electricity use by digital equipment and components will increase by 61% to 239 TWh in 2011, which represents 17% of total commercial electricity use.

Table 3-11
Commercial Electricity Use in 2001 (TWh)

Category	Total	Digital	Non Digital	% Digital	% of Digital Total
Digital segments					
High tech	43	43	-	100%	29%
Data centers	6	6.2	-	100%	4%
Digital equipment retailers	15	15	-	100%	10%
Subtotal digital segments	65	65	-	100%	44%
End uses in non digital segments					
Office equipment	38	38	-	100%	26%
Miscellaneous digital	59	21	38	35%	14%
Interior lighting	354	18	337	5%	12%
All other end uses	625	6	619	1%	4%
Subtotal end uses in non digital segments	1,076	83	994	8%	56%
Commercial Total	1,142	148	994	13%	100%

Table 3-12
Commercial Electricity Use in 2011 (TWh)

Category	Total	Digital	Non Digital	% Digital	% of Digital Total
Digital segments					
High tech	101	101	-	100%	42%
Data centers	18	18	-	100%	8%
Digital equipment retailers	18	18	-	100%	8%
Subtotal digital segments	137	137	-	100%	57%
End uses in non digital segments					
Office equipment	49	49	-	100%	21%
Miscellaneous digital	72	25	47	35%	11%
Interior lighting	415	21	394	5%	9%
All other end uses	742	7	735	1%	3%
Subtotal end uses in non digital segments	1,279	102	1,176	8%	43%
Commercial Total	1,415	239	1,176	17%	100%

Digital Segments

In the commercial sector, Primen typically segments customers into 13 building types: small office, large office, restaurant, retail, grocery, warehouse (refrigerated and non-refrigerated), education, health, lodging, and miscellaneous (which includes public assembly, business and personal services). For this project, Primen defined three additional categories because they are central to the digital economy—high-tech offices, data centers, and digital equipment retailers—which are described in the sections below.

High-Tech Offices

High-tech offices include telecommunications, banking, and research facilities. In 2001, high-tech offices consumed 18 TWh of electricity, the largest amount of all building types. These offices were identified as having a higher concentration of computing and network equipment;

therefore, 100% of the energy consumed in these companies was assigned to digital. Primen estimates that this will increase to 44 TWh of digital energy in 2011, which reflects an increase in use of computers, network equipment, servers, and telecommunication equipment over the next ten years.

Data Centers

Data centers include all data storage facilities, co-location facilities, and Internet service providers. Data centers are a fairly recent phenomenon and, therefore, represent only a small amount of floor space. However, the high concentration of network and computer equipment makes it unique in terms of energy use. In 2001, with only 17.9 million square feet of floor space, this segment consumed 4.3 TWh of energy. In 2011, energy use in data centers is expected to climb to 12.6 TWh. This increase represents the increase in floor space over the next ten years, as well as an increase in HVAC equipment to cool the equipment.

Digital Equipment Retailers

Primen defines digital equipment retailers as retail establishments that are engaged primarily in the distribution of digital products (such as Circuit City, Best Buy, and others). Primen estimates that 10% of the retail establishments fall into this category and we have assigned all of their activity and electricity use to the digital category. We arrived at the 10% number by comparing D&B counts for electronics, radio, TV, and household appliance retailers to the total number of establishments in the retail segment. These retailers account for 15 TWh of electricity use in 2001 and this to increase to 18 TWh in 2001.

End-Use Discussion

There are three primary digital end-use categories in the commercial sector: 1) office equipment, 2) miscellaneous digital equipment, and 3) lighting. All other end uses have small digital energy use, so Primen grouped them into a single category.

Office Equipment

Office equipment includes desktop computers, mainframes, servers, telecommunications equipment, electronic cash registers, audio/visual equipment, and UPS systems. Since office equipment is nearly all digital, Primen defines 100% of the electricity as “digital.” It accounts for 59 TWh of electricity sales in 2001, or 5% of the U.S. total. By 2011, Primen projects that office equipment electricity use will almost double to 103 TWh.

Miscellaneous Digital Equipment

Miscellaneous digital equipment includes medical equipment, security/surveillance systems, lab instruments, and other industry-specific equipment. Primen defines about 50% of medical equipment, including monitors, CAT scans, life support machines, etc., as “digital.” On average, electricity use by digital medical equipment is about 1 kWh per hour of use. Security or surveillance systems are present in approximately 20% of commercial buildings and consume approximately 0.6 kWh per hour of use. About 35% of lab instruments used in research facilities, such as centrifuges, scales, culture hoods, etc., are digital. They range from energy consumption of .001 kWh to 2 kWh per hour of use. In total, miscellaneous digital equipment accounts for 22 TWh in 2001 and 28 TWh in 2011.

Interior Lighting

Commercial interior lighting accounts for 369 TWh of sales in 2001, or 32% of the U.S. total. By 2011, commercial interior lighting will increase to account for 440 TWh of electricity sales. Lighting fixtures with electronic ballasts, daylight dimmers, occupancy sensors, timers, EMSs, and LED exit signs are included in the "digital" part of this end use. Fixtures with electronic ballasts account for 30% of interior lighting usage in 2001. Daylight dimmers and occupancy sensors can be applied to 50% of the floor space. The energy use of these is .01 kWh per hour of use. Timers are present in about 55% of the buildings and consume approximately .01 kWh per hour of use. EMSs also control interior lighting and are found in 10% of buildings, using .1 kWh per hour. In sum, these digital loads account for about 5% of the 2001 interior lighting load and 20% of the entire digital load. In 2011, the digital portion of electricity sales for lighting will be 22 TWh, which will be 13% of the entire digital load.

Other End Uses

This category includes HVAC, water heating, cooking, refrigeration, and exterior lighting. In 2001, Primen estimates that they used 625 TWh of electricity. In 2011, Primen estimates that they will use 742 TWh. Overall, the use by digital components is small, only 1% in 2001 and 2011, as described below.

Of the other end uses, HVAC is the largest component of digital load. The "digital" part of the HVAC system is the controls. There are two main types: energy management systems (EMSs) and microprocessors. EMSs are found in about 10% of the built-up systems in large buildings that condition about 32% of commercial floor space. The typical energy use of these controls is 0.1 kWh per hour. Microprocessors are found in about 12% of the packaged heating and cooling systems that condition about 29% of commercial floor space. The typical energy use of these controls is .006 kWh per hour of runtime for microprocessors. Programmable thermostats and digital displays for HVAC systems also contribute to the digital load, but when compared to the total energy use, are negligible.

The remaining end uses have a very small percentage of the energy considered digital, typically only the equipment display. The digital aspect of exterior lighting includes timers and motion detectors. Timers are in 65% of commercial buildings and typically use about .01 kWh per hour. Motion detectors are in 10% of buildings and consume .01 kWh per hour. In total, 3%, or 1.2 TWh of the 2001 exterior lighting is "digital." In 2011, the digital aspect will be 1.5 TWh. For commercial refrigeration, the digital display and LED lights are considered the "digital" part of the end use and accounts for 0.5%, of the energy used. In 2001, the digital part of refrigeration will be 0.5 TWh and in 2011 it will be 0.7 TWh. The digital displays on cooking equipment contribute only a very small fraction of a percent to digital loads: Primen has defined it as 0.5% of cooking electricity use. The digital loads associated with water heating include controls and digital displays. They account for only 0.5% of water heating electricity use.

Class 2: Digitally Controlled Processes

Class 2 is defined as process equipment, devices, and systems used to convert, control, and improve energy utilization or process performance of other end-use equipment and devices. It includes many electronic motor, lighting, and HVAC controllers that save energy or increase process productivity. It is also comprised of the equipment used in digitally controlled processes such as medical electronics, digital security systems, electronic assembly and manufacturing, two-way communications for digital devices, and continuous process manufacturing.

Examples of digitally controlled energy use include an ASD that controls a motor to provide speed control and/or energy savings, an electronic ballast that converts 60-Hz power to high frequency and improves the lumen per watt performance of fluorescent lamps, and a power conditioner that will regulate voltage to better serve sensitive or critical equipment. All of these devices improve energy utilization or process performance by applying digital technology. This class of digital end-use may also be characterized as Smart Utilization Equipment. Appendix B provides basic data for the SIC categories previously defined under Class 2 – Digitally Controlled Processes.

Electrical Usage for All Industrial Digitally Controlled Loads

Approximately 3 billion embedded CPUs are sold each year, with smaller (4-, 8-, and 16-bit) CPUs dominating by quantity and aggregate dollar amount. It is thus quite difficult to determine the exact electrical consumption of all digitally controlled processes currently in use. Based on an estimated total number of automation units with a maximum load per unit, Primen estimates the total annual electrical usage of industrial digitally controlled loads to be 20.69 TWh (see Table 3-13). Automation Units are defined to be single-phase, control power loads, including PLCs, AC and DC control power, sensors, motor starters, and all other forms, fed from a single source. A 1-kVA rating was estimated as an average-size control power.

Table 3-13
Estimated Annual Electrical Consumption of Digitally Controlled Automation

	Millions	Value	Units
Total Enclosed Manufacturing Space	8435.8	8,435,800,000.00	Square Ft
Estimated Square Foot Per Automation Unit		2500	Square Ft
Estimated number of automation units		3,374,320.00	Automation Units
Estimated Max Load Per automation unit (kVA)		1	kVA
Estimated Max Load Per automation unit (kW) (based on 0.7PF)		0.7	KW
Estimated Total Load (kW)		2,362,024.00	kW
Estimated Total Load (MW)		2,362.02	MW
Estimated Yearly Electrical Usage		20,691,330.24	MWH

Class 2: Digital Control Equipment

Digital control devices such as ASDs are a prime example of Class 2 digital end use. In 1994, ASDs were used in 4.4 percent of industrial motors, equivalent to an electricity consumption of about 11 TWh (Xenergy 1998). The potential growth of this market is estimated at 14% of industrial motor use (equivalent to 78 TWh). As noted in Table 3-14, in 1997 ASDs accounted for some 25 TWh and were used on 9% of all motors, an increase of 50% from 1994. But exactly what portion of the electrical usage should be considered digital?

Table 3-14
Electrical Consumption Associated with Drives 1997 Data (Source: U.S. Industrial Motor Systems Market Assessment Opportunities 1998)

Horsepower Class	Motor Systems with ASDs		Energy in Systems with ASDs	
	Number	% of Total	GWh/Year	% of Total
1 – 5	767,807	11	3,753	13
6 – 20	254,862	8	4,431	7
21 – 50	46,126	4	2,545	3
51 – 100	13,536	4	2,888	4
101 – 200	11,661	5	2,955	4
201 – 500	1,873	2	1,421	2
501 – 1000	820	3	3,127	4
1000+	644	6	4,203	5
All Motor Systems	1,097,328	9	25,325	4

Class 2: Electronic Lighting

Overall, lighting is estimated to account for 23% of national electricity consumption. Of national lighting energy use, residential lighting is estimated to constitute about 20%; commercial lighting, 60%; industrial lighting, 16%; and other uses, 4%. The commercial lighting segment was estimated to consume 4 quads (365 billion kWh) of energy in 1997.

Incandescent lamps represent the major type of common lamp used in residential lighting. Commercial lighting includes both tubular fluorescent and high intensity discharge (HID) lamps; the split is approximately 2/3 fluorescent to 1/3 HID. Industrial lighting includes both fluorescent and HID, while street lighting is largely HID.

Commercial interior lighting accounts for 369 TWh of sales in 2001, or 32% of the U.S. total. Lighting fixtures with electronic ballasts, daylight dimmers, occupancy sensors, timers, EMSs, and LED exit signs are included in the “digital” part of this end use. Fixtures with electronic ballasts account for 30% of interior lighting usage in 2001. Daylight dimmers and occupancy sensors can be applied to 50% of the floor space. The energy use of these is .01 kWh per hour of use. Timers are present in about 55% of the buildings and consume approximately .01 kWh per hour of use. EMSs also control interior lighting and are found in 10% of buildings, using 0.1 kWh per hour. In sum, these digital loads account for about 5% of the 2001 interior lighting load and 20% of the entire digital load. In 2011, the digital portion of electricity sales for lighting will be 22 TWh, which will be 13% of the entire digital load.

Industrial Sector

Primen defines the industrial sector as “manufacturing,” SIC codes 20 through 39. Primen has not included mining, agriculture, and construction. Primen estimates that industrial electricity use in 2001 is 1,067 TWh. Primen projects that electricity use will increase by 18% over the next 10 years to 1,255 TWh.

To forecast changes in energy use by SIC, Primen combined projected changes in output ($) and energy intensity (kWh/$) to get an overall change in electricity use (kWh). Primen also used output forecasts from the Bureau of Labor Statistics (BLS) because it had forecasts by SIC and by some of the “all-digital” sub-segments. DOE’s Annual Energy Outlook had forecast a change of -1.2% per year in energy intensity for the overall manufacturing sector for the period of 1999 through 2011.

Table 3-15 provides a breakdown of electricity use by digital segments and by end uses in non-digital segments. It also identifies the fraction of electricity use that comes from digital equipment and components. Overall, digital equipment and components account for 193 TWh or 9% of total commercial electricity use in 2001.

Table 3-16 presents similar information for 2011. By 2011, Primen projects that electricity use by digital equipment and components will increase by 61% to 150 TWh, which represents 12% of total industrial electricity use. Our assumptions behind these numbers are provided below.

Table 3-15
Industrial Sector Electricity Use in 2001 (TWh)

Category	Total	Digital	Non Digital	% Digital	% of Digital Total
Digital segments					
3341 – Computer	7.7	7.7	-	100%	8%
333295 – Semiconductor	1.1	1.1	-	100%	1%
3335 – Metalworking	4.1	4.1	-	100%	4%
3342 – Communications	4.6	4.6	-	100%	5%
3343 - Audio & visual	0.8	0.8	-	100%	1%
3344 - Electronic component	21.5	21.5	-	100%	23%
3346 – Magnetic & optical	2.1	2.1	-	100%	2%
339112 - Surgical & medical	1.8	1.8	-	100%	2%
2245 - Navigational/control	8.3	8.3	-	100%	9%
Subtotal digital segments	52	52	-	100%	55%

End uses in non digital segments					
Automated process control	32	32	-	100.0%	34%
Facilities support	14	7	7	50.0%	8%
Machine drive	564	2	562	0.3%	2%
Lighting	56	0	55	0.6%	0%
Other end uses	350	1	349	0.2%	1%
Subtotal end uses in non digital segments	1,015	42	974	4.1%	45%
Industrial total	1,067	93	974	9%	100%

Table 3-16
Industrial Sector Electricity Use in 2011 (TWh)

Category	Total	Digital	Non Digital	% Digital	% of Digital Total
Digital segments					
3341 – Computer	27.1	27.1	-	100%	18%
333295 - Semiconductor	3.7	3.7	-	100%	2%
3335 – Metalworking	4.9	4.9	-	100%	3%
3342 – Communications	6.6	6.6	-	100%	4%
3343 - Audio & visual	1.0	1.0	-	100%	1%
3344 – Electronic component	37.5	37.5	-	100%	25%
3346 – Magnetic & optical	3.6	3.6	-	100%	2%
339112 - Surgical & medical	2.2	2.2	-	100%	1%
2245 - Navigational/control	11.5	11.5	-	100%	8%
Subtotal digital segments	98	98	-	100%	65%
End uses in non digital segments					

Automated process control	38	38	-	100.0%	25%
Facilities support	17	8	8	50.0%	6%
Machine drive	637	4	632	0.7%	3%
Lighting	66	1	66	1.3%	1%
Other end uses	400	1	399	0.2%	1%
Subtotal end uses in non digital segments	1,157	52	1,105	4.5%	35%
Industrial total	1,255	150	1,105	12%	100%

Digital Segments

The nine digital segments of the industrial sector shown in Table 3-15 and Table 3-16 account for 52 TWh of electricity use in 2001, or 55% of the digital total. Our forecast of growth in these segments comes from the Bureau of Labor Statistics, which projects that the semiconductor manufacturing segment will grow by an average of 7% per year from 2000 through 2010 and that the computer and peripheral manufacturing segment will grow at an annual rate of 14.8% per year over the same period. Based on these growth forecasts, Primen projects that electricity use in the nine industrial segments will increase by 89% from 52 TWh in 2001 to 98 TWh in 2011.

End-Use Discussion

The use of digital equipment and components in non-digital segments is discussed below.

Process Energy and Process Controls

Primen defines process uses as boiler fuel, process heat, process cooling, electrochemical process, and other process. These processes all use digital process controls. Primen estimates that process controls account for 32 TWh of electricity use in 2001, or 34% of the digital total. Primen projects that this amount will increase to 38 TWh in 2011. (Assumptions behind these values are forthcoming.)

Facility Support

Facility support consists of equipment that is not related to process, HVAC, or lighting. Primen estimates that electricity use for facility support was 14 TWh in 2001 and that it will increase to 17 TWh in 2011. Primen estimates that 50% of facility support is made up of office equipment, telecommunications, and alarm systems, all of which are digital loads. This resulted in 7 TWh of digital use in 2001, or 7.5% of the entire digital load, and 8 TWh, or 5.6%, in 2011.

Machine Drives (Motors)

The machine-drive or motor end use is the single largest user of electricity in the industrial sector. In 2001, Primen estimates that motors used 564 TWh, which is more than half the industrial total. In 2011, Primen projects that motor use will increase by 13% to 637 TWh.

Motor controls include adjustable-speed drives (ASDs), which are digital controls. Primen estimated the energy use of ASDs using the U.S. Industrial Market Assessment, which estimated that ASDs had a penetration of 4.4% of motor energy use in the manufacturing sector in 1997. It also estimated a total potential market of 14%. Based on this information, Primen assumes that the ASD penetration is 6.5% in 2001 and 14% for 2011.

ASDs account for about 5% of motor/controller system energy. Therefore, Primen estimates that ASDs account for 0.33% of total motor use in 2001 (2 TWh) and 0.70% of total machine drive energy use in 2011 (4 TWh).

Other End Uses

All other end uses, which include HVAC, lighting, on-site transportation, and other non-process loads, use about 350 TWh in 2001. In 2011, Primen projects that this will grow to 400 TWh. Across the category of other end uses, Primen assumed that only 1% of total electricity use is associated with digital controls.

Class 3: Digitally Enabled Enterprises

Class 3 is defined as business enterprises that exist because of the convergence of electronics, information technology, and communications. “Digitally enabled” includes existing business enterprises that are being transformed by these technologies, such as credit institutions, broadcasting companies, and e-businesses. Class 3 also includes waste minimization and increases in efficiency directly attributable to digital equipment and processes. Appendix C provides basic data for the SIC categories previously defined under Class 3 – Digitally Enabled Enterprises.

4
ECONOMIC AND TECHNOLOGY TRENDS: TODAY AND TOMORROW

Barriers and Obstacles

A number of technology factors and trends will play an integral part in shaping the future growth of the digital society, including microprocessor improvements, telecommunications transformations, and continued growth and evolution of the Internet. Taking these as the cornerstones of growth, there are two primary considerations when looking to the future of the digital economy. The first is, “Which trends are dominating now and which will continue to dominate?” The other question is, “What are the barriers that keep other trends from becoming dominant, and which of these will remain in place for the long term verses the short term?”

In response to these two basic questions, the following chapter is a discussion of both the economic and technological trends occurring with microprocessors, telecommunications, the Internet, and networking that will have significant implications on the future of the digital society.

Microprocessor Power and Speed Growth

Chip designers are currently designing processors with the intent of minimizing recurring system costs, especially those arising from high power demand and electrical consumption, while retaining a high level of reliability. This requires attention to details at all stages of the design. Reducing power requirements, without negatively influencing either the performance or reliability of the processor in any significant way, is a major challenge with millions of dollars being allocated to this specific research area this year.

The power dissipation of modern processors is rapidly increasing along with the clock frequency speed in megahertz (MHz) and the number of transistors required for a given implementation. Figure 4-1 shows the power consumption trend of processors introduced by Intel®, a major microprocessor manufacturer, over the past 15 years. While there are a few outlying data points, the general trend is for maximum processor power consumption to increase by a factor of a little more than two times every four years.

The increase in power usage has so far helped decrease the processing times of operation. But at the same time, there is a growing disparity between the maximum power demand of a processor and the typical power required by that processor. This trend is the result of the significant increase in transistor count required to attain the desired peak performance targets.

- Personal Computers (PCs) central processing units (CPU) and monitors are estimated to account for only 2% of all residential electricity use in 2000
- PC CPUs, monitors, and laser printers are estimated at 3% of commercial electricity use

- Electrical consumption by mainframes and microprocessors declined by 50% between 1990 to 2000, while the density of the chips has increased by up to 30%.

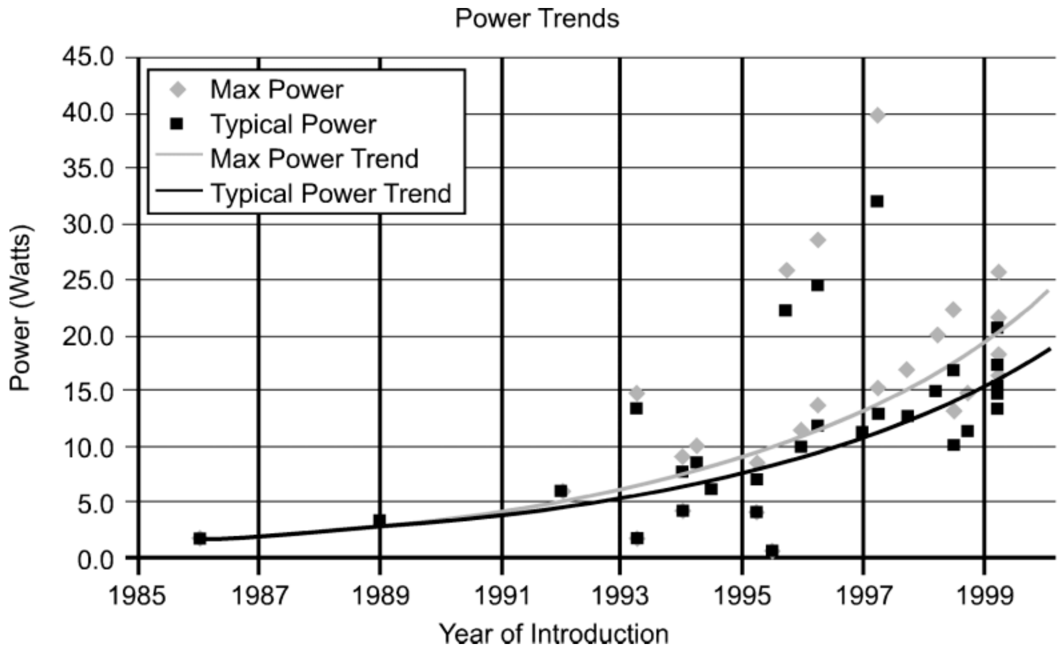

Figure 4-1
Trends in CPU Power Requirements[40]

Packaging

In the past, the increase in processor speeds has typically been closely followed by an increase in the physical size of the chip. This is due to the increased number of transistors required for increased speed, which boosts the size, even though the transistors themselves continue to decrease in size. Therefore, perhaps the ultimate challenge is to increase power conversion density (placing more and more silicon in smaller and smaller packages). But advances have been made in this area, and manufacturers are now offering “super” packages in both heat-sinkable (through-hole) and surface-mount configurations, which double the die-to-footprint ratio to 30 percent or more while cutting internal resistance in half and permitting dramatic increases in power density for power supplies and inverter motor drives[41] Additional advances in the future will include three-dimensional and chip-scale packages that integrate multiple device types into a single package, resulting in densities about double the current state-of-the-art. High-volume applications will be achieved through integration of power devices, signal devices, and passive components, which will also result in noted density improvements.

40 http://developer.intel.com/technology/itj/q12001/articles/art_4c.htm, viewed May 25, 2001.

41 Alex Lidow, CEO, International Rectifier, *The Power Conversion Process as a Prosperity Machine, Part II — Power Semiconductor Road Maps*, March 16, 1999.

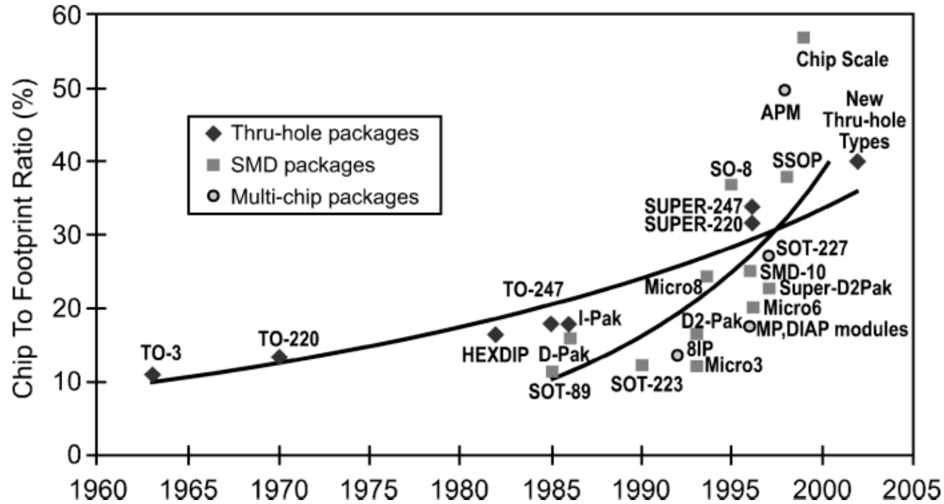

Figure 4-2
Trend in Package Die-to-Footprint Ratio for Heat Sinkable, Surface Mounted, and Multi-Chip Packages[42]

Larger and more complex processor chips are typically more expensive to produce, since the likelihood of problems with a piece of silicon increases with its size, and the added size makes the design of compact devices using the chips more challenging. However, even with the drawbacks, there are noteworthy advantages to these larger and more complex chips. Principally. it is easier to dissipate the heat in a chip with a larger surface area. Normally, this would mean that a larger heat sink could be used, though this would only add to the large profile of the chip. However, with recent innovations, this could mean spray-cooling method could be used, where the electronic equipment is sprayed with a thin dielectric film using miniature atomizer arrays and the fluid evaporates to extract heat, maintaining devices at constant low temperature.

Increased speeds, lower power demands, and reduced logic voltage will certainly enhance overall performance as well as energy efficiency of microprocessor-based equipment and the digital society as a whole.

For example, engineers at Intrinsity, Inc., in Austin, Texas, say the ultra-fast processor they have developed is really “cool” – meaning they operate at much lower temperatures than today’s fastest chips. The 2.2 GHz chip is made using a process known as Fast14 (the atomic number of silicon) Technology and uses an automatic generation of dynamic logic circuits that are as powerful as conventional static circuits. New chips can be developed quickly because dynamic circuits allow easier data flow. In addition, the processor uses a clocking scheme to reduce the heat it generates making it even more attractive since typically high-speed chips require more power than the batteries embedded in devices can handle. As a result, Intrinsity’s new cool chip uses between 5 and 15 watts. “The other guys will burn 80 to 120 watts of power,” CEO Paul Nixon says. The “other guys” include Intel, which has announced its own 2.2-GHz chip. The chips could be seen within the near future and are expected in embedded applications such as

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[42] Alex Lidow, CEO, International Rectifier, *The Power Conversion Process as a Prosperity Machine, Part II — Power Semiconductor Road Maps*, March 16, 1999.

cell-phone towers, digital video, and medical-imaging machines. However, only time will tell as to whether the market will adopt this new technology.

Other manufacturers are also announcing their respective versions of a 2 GHz chip. This is a case in point that Moore's Law, which states that processing power doubles every 18 months, is still valid. Intel indicates that the 2-GHz mark isn't merely a psychological milestone, but a gateway to next-generation applications, such as real-time streaming audio and video in the office and peer-to-peer computing.

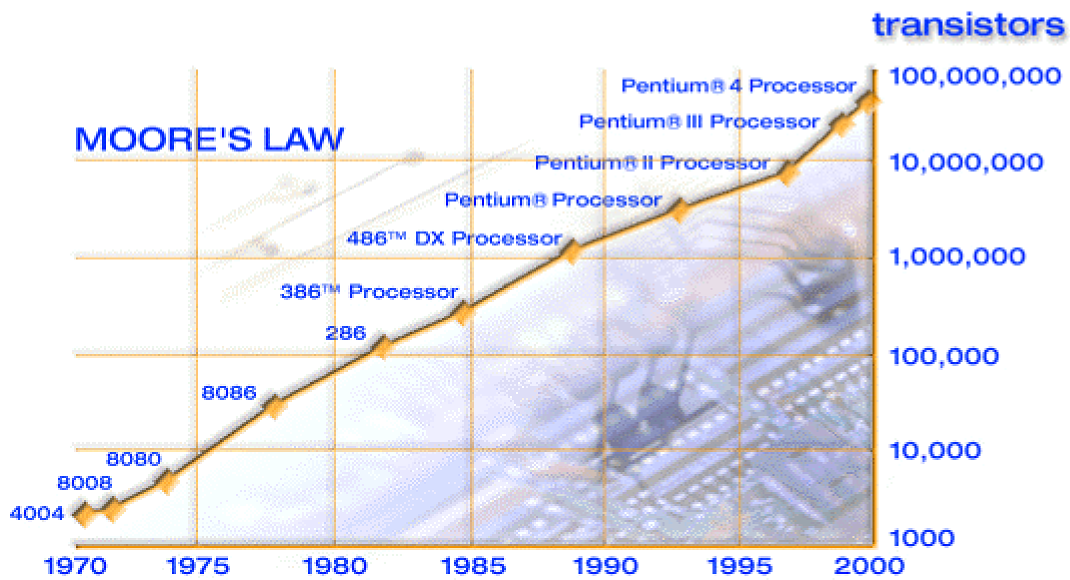

Figure 4-3
Moore's Law

Cooling challenges are seemingly being met full force according to a recent article entitled "Too Hot to Handle" by Elizabeth Corcoran, *Forbes*, April 2, 2001:

"New cooling tricks are starting to emerge. In late February, the fledgling Incep Technologies in San Diego introduced a technique for packaging together a microprocessor, a logic board for regulating power to the chip and a heat sink. Even though such "encapsulation" could cost $200 per unit, Incep President James Kaskade contends that it both cools the chips and saves space inside the box.

Isonics Corp**.** in Golden, Colo., a maker of specialty materials and chemicals, is proposing a new material: a "purer" version of silicon called Si-28, which channels out heat better than conventional silicon. The silicon in typical wafers is a blend of three silicon isotopes. Sifted down to just the Si28 isotope, Isonics' wafer conducts heat better.

Even though Si28's thermal properties are attractive, changing materials could be an expensive option, adding at least 25% to the cost of the wafer. Isonics Chief Executive James Alexander says he needs committed partners before manufacturing the first wafers. He claims that Advanced Micro Devices, among others, is experimenting with the materials."
Intel's astonishing march toward ever-denser chips comes with a cost: skyrocketing energy

demands. The prospect of 100-kilowatt chips has designers scrambling for solutions. Projection figures assume no advances in energy-efficiency techniques.[1] Leakage is the dissipation of energy as a result of imperfect transistor function (*Source: Intel)*.

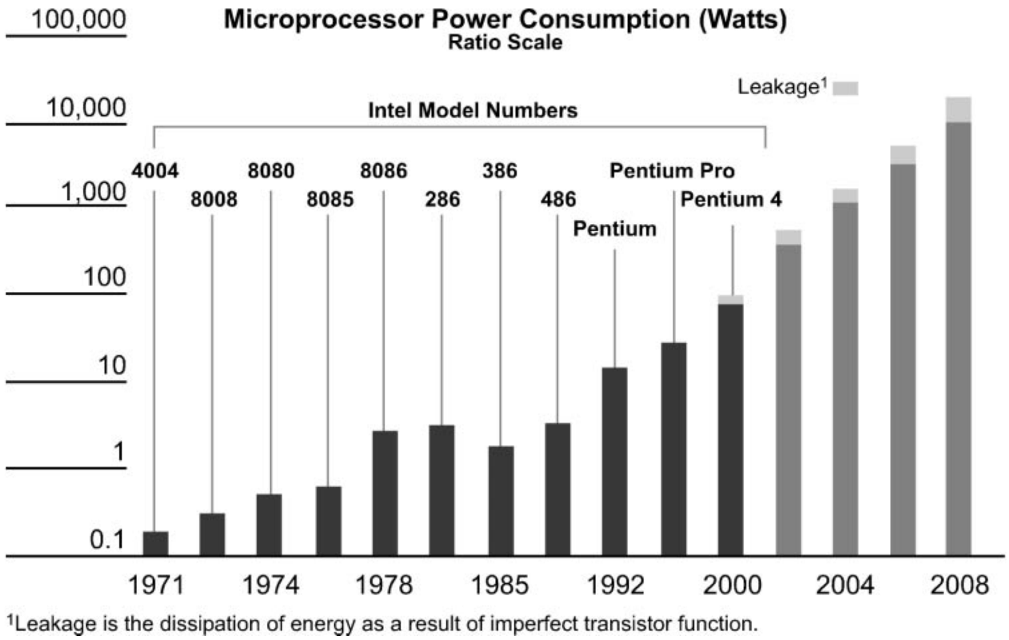

Figure 4-4
Estimated Microprocessor Consumption in Watts from 1971-2008

Embedded Solutions and Computing without Computers

For years there has been an old and ongoing "software vs. hardware" conflict, which has, historically, boiled down to the following: It's cheaper and faster to "code" processor functions into hardware, but also very inflexible once the chip design is complete. It's extremely flexible to code processor functions into software, which the processor reads and executes, but this requires development and maintenance of complicated micro-code and higher-level languages, plus puts the onus on the user/application engineer to program the processor.

There is some viability of this new approach to rapid design that allows application specialists to increase productivity and take concepts directly to silicon and illustrates case study for development of an Internet re-configurable platform which can support apps such as VOIP and MP3. Basically, the claim is that a user can get CPU-like flexibility through re-configurable logic and a design process similar to conventional software. (Source: www.celoxica.com.)

A good example of this ongoing conflict is floating point mathematics. Originally, these were done almost entirely by software. This was slow and required a lot of micro-code to maintain. Now, it is all done in a hardware FPU and the software code is very simple.

For other applications, imagine, for instance, that MSWord was coded 100% in hardware: allowing virtually instantaneous response and stability and, technically, free of "computing," since it is all in hardware. One wouldn't even necessarily need an operating system like Windows. However, also imagine the complexity of the hardware design, and the further difficulty of making any changes to behavior after the fact.

Celoxica appears to have developed an intermediate hardware-based approach where, in fact, the processing is done in hardware quickly and (presumably) at low cost. However, the hardware itself is at least somewhat "programmable" or at least re-configurable - reminiscent of the old EPROM technologies where one would write a "program" that was then burned permanently (or semi-permanently) into a chip.

Another approach that is gaining attention is hardware/software co-design. Approximately 3 billion embedded CPUs are sold each year, with smaller (4-, 8-, and 16-bit) CPUs dominating by quantity and aggregate dollar amount. Yet, most research and tool development seems to be focused on the needs of high-end desktop and military/aerospace embedded computing. This paper seeks to expand the area of discussion to encompass a wide range of embedded systems.

The extreme diversity of embedded applications makes generalizations difficult. Nonetheless, there is emerging interest in the entire range of embedded systems and the related field of hardware/software co-design.[43]

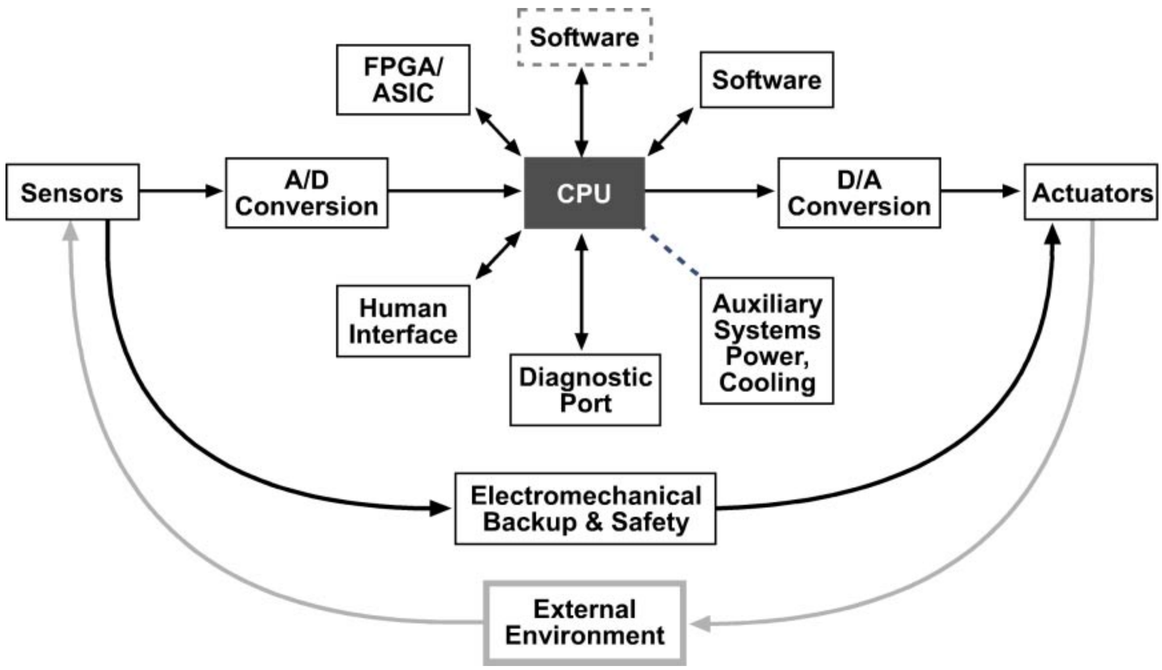

Figure 4-5
Possible Organization for Embedded Systems

Some differences with desktop computing may be:

- The human interface may be as simple as a flashing light or as complicated as real-time robotic vision.
- The diagnostic port may be used for diagnosing the system that is being controlled—not just for diagnosing the computer.

[43] Philip J. Koopman, Jr., *Embedded System Design Issues: The Rest of the Story*, preprint of paper published in Proceedings of the International Conference on Computer Design (ICCD '96).

- Special-purpose field-programmable (FPGA), application-specific (ASIC), or even non-digital hardware may be used to increase performance or safety.
- Software often has a fixed function and is specific to the application.

In addition to the emphasis on interaction with the external world, embedded systems also provide functionality specific to their applications. Instead of executing spreadsheets, word processing and engineering analysis, embedded systems typically execute control laws, finite state machines, and signal processing algorithms. They must often detect and react to faults in both the computing and surrounding electromechanical systems, and must manipulate application-specific user interface devices.

Recent interest in hardware/software co-design appears to be a step in the right direction. This approach allows for give and take between hardware and software that are critical for more cost-effective embedded systems. Some related issues and challenges regarding software solutions include:[44]

- The amount of software in an embedded device doubles every 18 months.
- Defect densities are stable over the last 20 years: 0.5-2.0 software failures/1000 lines.
- Software testing accounts for 50% of pre-release costs and 70% of post-release costs.
- $200 billion are spent per year addressing software disruption.
- Run-time errors account for 50-60% of all software errors.
- $85 billion per year of revenue are lost due to system downtime.
- 84% of software development projects are not completed on time.
- 58% of completed software development projects don't achieve the desired functionality.
- More than 50% of all business critical software projects are late, over budget, or deployed with reduced functionality.
- 31% of all software development projects fail completely.

Enhancements in Power Supplies and Energy Efficiency

Today, both government and industry are setting new standards and guidelines for energy efficiency in power supplies and applications. Energy Star™, which was introduced by the U.S. Environmental Protection Agency in 1992 as a voluntary labeling program, has created a dynamic government/industry partnership exceeding 1,600 manufacturers in order to promote energy efficient products including consumer electronics. Driven by consumer and industry demands, computers and related systems have reduced electrical consumption by several factors.

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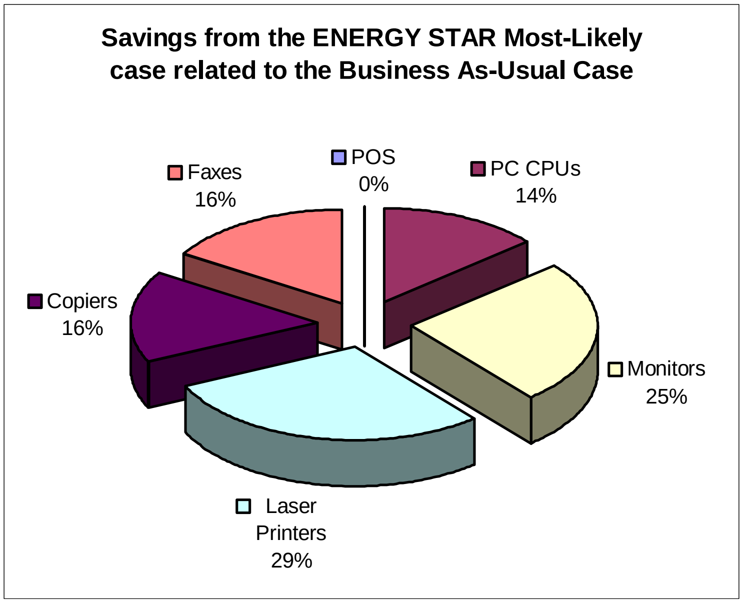
[44] PolySpace Technologies http://www.polyspace.com/profile.htm



POS = Point of Sale devices

Figure 4-6
Energy Star's Impact on Power Systems

With its initial intent to reduce air pollution through increased energy efficiency, Energy Star now works with more than 7,000 partners striving to improve the energy efficiency of products, homes, buildings, and businesses. Energy Star helps to identify the most energy efficient products and covers some 11,000 products in more than 30 categories that bear the Energy Star Label. Energy Star offers labels to identify the most energy-efficient homes, buildings, office equipment, heating and cooling equipment, lighting, major appliances, and home electronics. The most likely level of savings represents the annual output of three 1000 MW power plants and results in net benefits to society exceeding $1 billion per year after the year 2000.

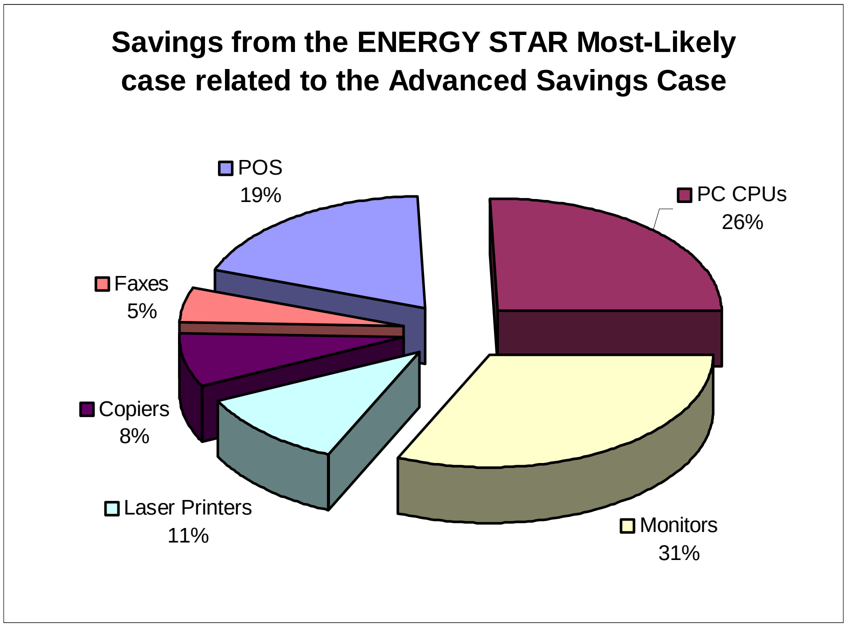


Figure 4-7
Energy Star's Impact on Power Systems

The industry, prompted by programs such as Energy Star, has strived to keep pace with the public demand for increased energy-efficient power supplies while providing increased speed and processing capabilities. New power management schemes are visible in a number of microprocessor companies, including AMD and Intel.

- Total electricity used by office equipment is projected to grow from 58 TWh in 1990 to 78 TWh in 2010 in the absence of Energy Star.
- In the worst case, the Energy Star programs will still result in commercial sector energy savings of a minimum of 10 TWh/year in 2010.

Among microprocessor manufacturers, AMD was recognized for supporting both the Advanced Configuration and Power Interface (ACPI) specification and the Energy Star Tier 2 computer specification in both their Athlon™ and Duron™ processor families. This allows PCs using the processors to consume 15 watts or less when in sleep state, a 50% reduction from the sleep state power demand of systems that do not support ACPI.

As of the year 2000, in Energy Star's most-likely case, about half of the Energy Star compliant PC CPUs are enabled, as are 70% of the monitors, 90% of the copiers, and 100% of the fax machines and laser printers. It results in annual savings of 11 TWh in 2000 and projected 17 TWh in 2010, savings reaching $900 million/year in 2000 and projected at $1.4 billion/year in 2010.

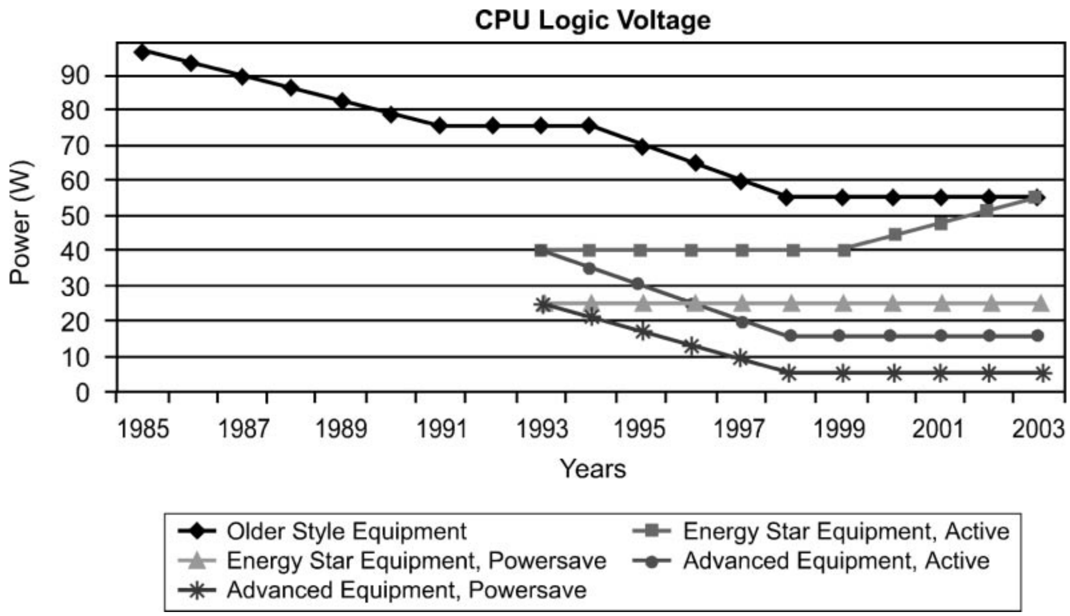


Figure 4-8
CPU Power Requirement History

Typical baseline Unit Energy Consumption (UEC) for PC CPUs in 2005 is about 170 kWh/year, with Energy Star equipment reducing this by slightly less than 50%, to 90 kWh/year. Most of this reduction is attributable to savings in the Standby and Suspend modes, with only a slight reduction attributable to savings in Active mode power. Baseline PC CPUs show reductions in UECs relative to the 1990 stock of about 30%, from 240 kWh/year to 170 kWh/year, which is caused by reductions in microprocessor and peripheral power use for desktop machines. These improvements have been driven by the economics of chip manufacturing as well as by the manufacturer's desires to fit more peripherals into smaller spaces, an effort that requires heat reductions and hence efficiency improvements.

Internet Usage and Economic Trends

Another significant factor in the future of the digital economy is no doubt the Internet itself and the continued explosion of growth and usage. It is difficult to image life without this global medium. But it was only a little more than a decade ago that Tim Berners-Lee and scientists at the European Organization for Nuclear Research (CERN), interested in simplifying retrieval of research documents, designed the World-Wide Web (WWW) concept in 1989. By 1991, CERN had developed a "browser/editor" program and had coined the name "World Wide Web" for the program. The innovative program was initially released for free on FTP (File Transfer Protocol) sites.

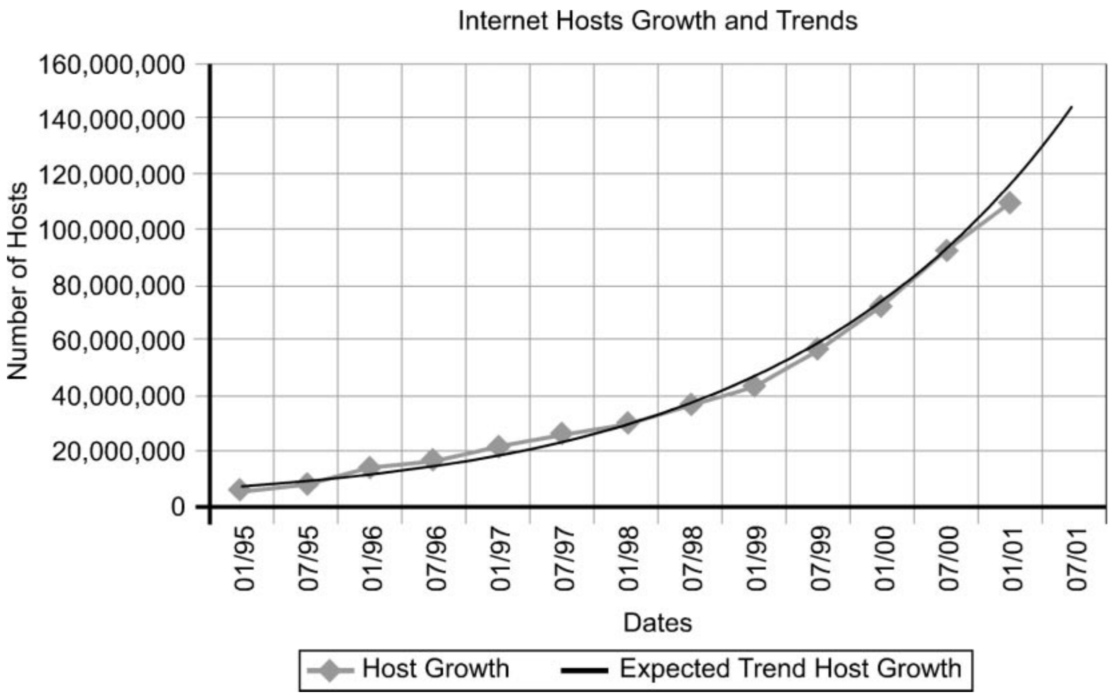


Figure 4-9
Internet Hosts Growth and Trends

Once the entire dial-and-retrieve-language had been developed and simplified, steps were taken to design an improved "browser" system. By the end of 1992, there were only 50 web sites in the World; a year later, the number had only reached 150. However, once the language protocol that allowed the links to be hidden behind text—Hypertext Markup Language (HTML)—and activated by a click of the 'mouse,' the Internet soon exploded at an extremely rapid pace. For instance, the number of Americans using the Internet had grown from fewer than 5 million in 1993 to as many as 62 million by 1997. The number of names registered in the domain name system (DNS) grew from 26,000 in July 1993 to 1.3 million in four years. Over the same period, the number of hosts connected to the Internet expanded from under 2 million to over 20 million. At this rate, the projected number of hosts connected to the Internet by the fall of 2001 will exceed 130 million.

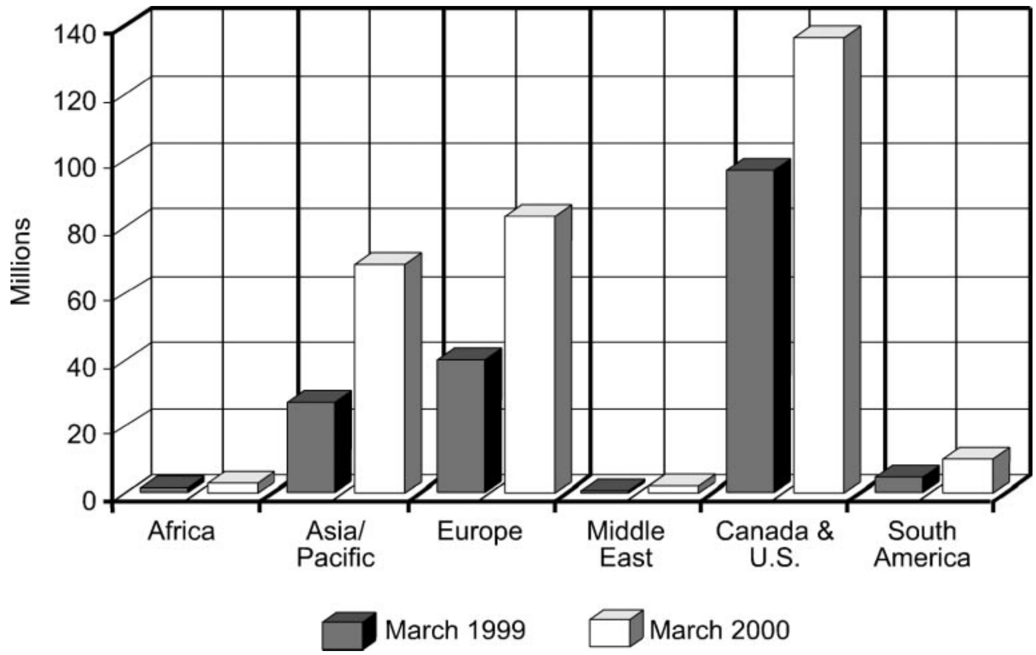


Figure 4-10
Internet Access Growth

Even with so many individuals and businesses using the Internet today, the bulk of the Internet infrastructure is primarily made up of private networking facilities in educational and research institutions and in government organizations across the globe. However, many of the newer data centers are being operated by companies ranging from small-town service providers specializing in regional business services to consumer Internet service providers that are diversifying to large backbone operators.

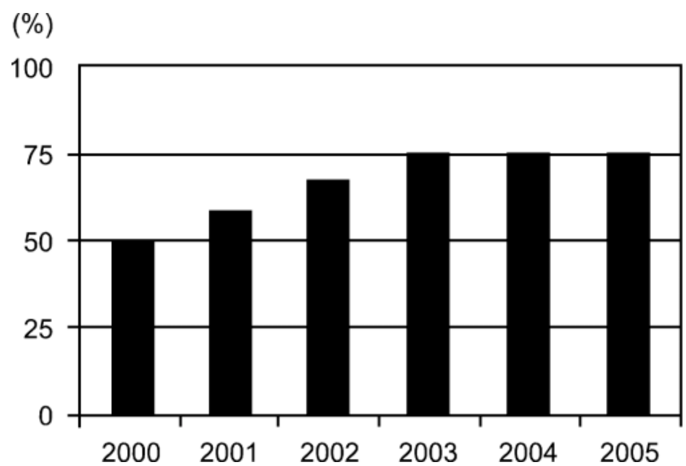


Figure 4-11
Percent of U.S. Population "Online" Projections (Source IDC.com)

So, just what is it that drives this power hungry infrastructure? Simply put, consumer demand is the force behind the steering wheel. Even in just the last five years, the Internet and web technologies have evolved through many generations.

- E-commerce activity for the year 2000 will reach $132 billion worldwide, more than double the $58 billion reported in 1999, according to ActivMedia.
- Electronics, including audio/video devices and PC add-ons such as scanners and printers, are estimated to account for 10 percent of all residential electricity use in 2001.

According to the Global eCommerce Report in July 2000, 10% of worldwide Internet users shop online (based on a statistical analysis survey of online consumer shopping in 27 countries, defined as users who have bought or ordered online in the last month). The United States, Japan, and Norway have the highest percentage of users who shop online (27%, 20%, and 19%, respectively).

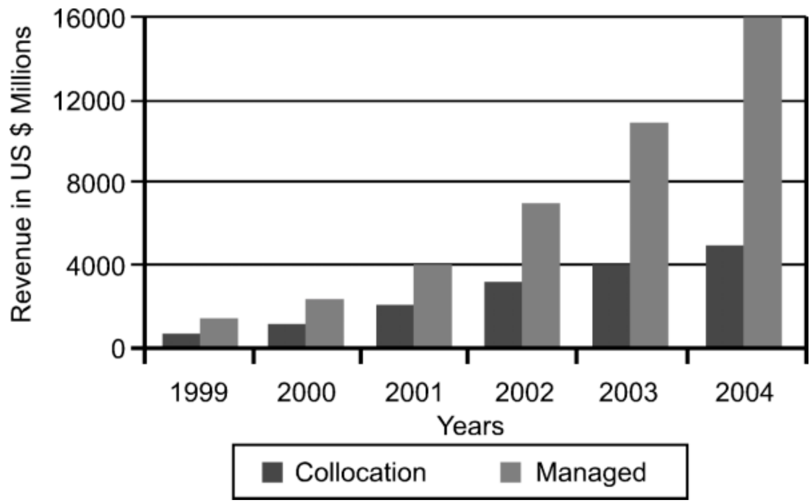


Figure 4-12
Dedicated Web Hosting Market Growth

Worldwide Christmas/holiday sales were predicted to be approximately $19.5 billion in 2000, with the U.S. accounting for nearly half, an increase of 178% from the $7 billion sales recorded in 1999 from November 01 to December 31, according to the Gartner Group, a major Internet forecasting company. North America will account for more than half of the worldwide online sales in this period this year, with a 55% share. Europe and Asia/Pacific are projected to grow 96% and 91%, respectively, with a combined market share of 36%.

In the middle of all this Internet power hungry E-Business, the data centers, Internet hotels, telecom hotels, and server farms represent some of the electric utility industry’s largest new customers, but serving them poses special challenges for utilities and industry alike. Typical loads demand extremely reliable power and quality while using several times the load densities (watts per square foot – wpsf) of a normal office space. However, there seems to be some discrepancies between requested building demand and what is actually used once these facilities start operating. In fact, the Edison Electric Institute's Steve Rosenstock explains: “The companies building server hotels have been working with developers and asking for 150 to 200 watts per square foot. But our members have been measuring what they're actually using after installation. It's closer to 25 to 40 watts per square foot.”

In addition, the physical “clustering nature” of these facilities in order to achieve and maintain the shortest distance from the key telecommunication/fiber networks adds to the complexity of serving the loads. These and other related technical challenges heighten the necessity for new and innovative approaches to power structuring and planning.

Internet influences also come from service providers ranging from government-supported organizations to small startup companies. These Internet Providers (IP's) often cut costs by engineering (or reengineering) their networks to optimize the transport of packet traffic. Some service providers also support circuit-switched traffic and multiplexing, allowing them to efficiently consolidate more types of traffic on the same infrastructure. In this fiercely competitive market, consolidation leads to enormous cost savings that can determine the survival of a provider. Successful providers will likely be those who differentiate themselves and transform the commodity service into value-added services that provide a higher return on investment.

Influences on E-Businesses

Many thought that there would be no end to the escalation of E-business through start-up "dotcom" companies. However, time proved differently and in January 2000, the dotcom bubble burst and many investors lost nearly everything. According to webmergers.com, between January 2000 and May 2001, more than 493 substantial Internet companies perished, with more than half of those losses in the first five months of 2001.

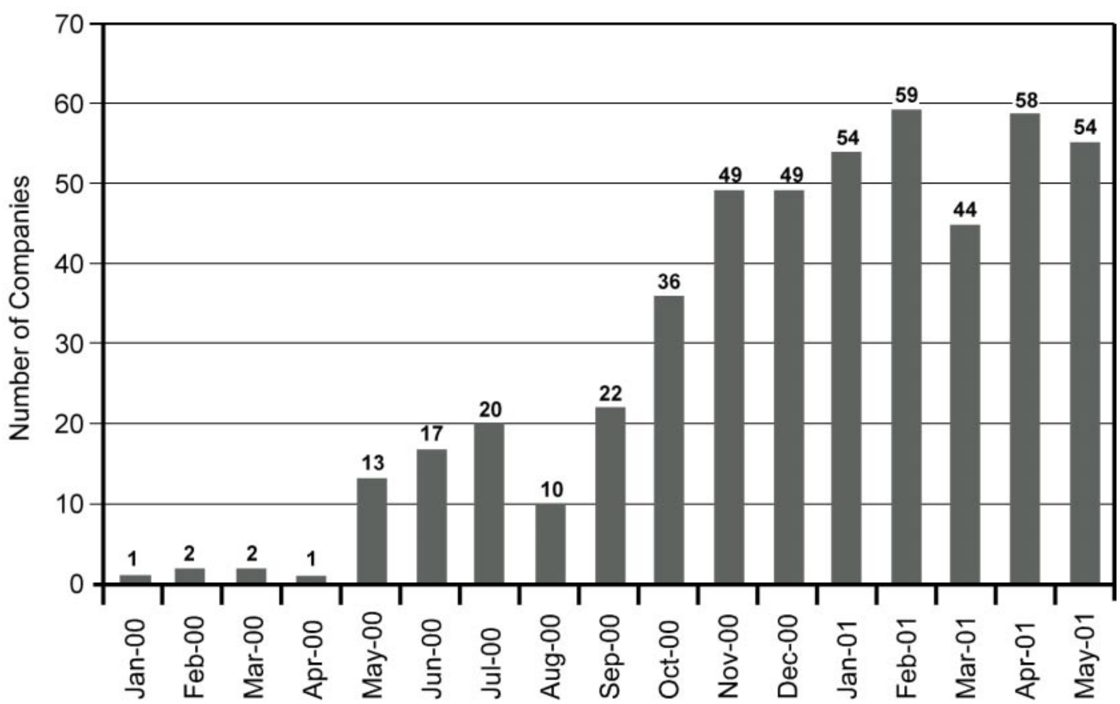


Figure 4-13
Closed/Bankrupt Internet Related Companies

In its "Mid-Year Report: Internet Shutdowns Appear to Reach Plateau," Webmergers.com, includes these additional statistics:

- 53 Internet firms shut down in June 2001, one less than at the same point in May.
- In June 2000, 17 Internet companies shut their doors.

- At least 555 Internet companies have folded since January 2000.
- The first half of 2001 has accounted for nearly 60% of all shutdowns to date.
- More than 9 times as many companies shut down in the first half of 2001 as in the first half of 2000 (330 in 2001 versus 36 in the same period in 2000).
- California's share of the misery remains at 32% of the first half's shutdowns, exactly the same percentage as for all of 2000.

As a result, investors in such companies are much more likely to be conservative and result oriented in the future more than ever before. This trend also indicates a migration increasingly away from B2C e-commerce and toward properties that provide Internet access, infrastructure, or consulting services to a business or general audience. In addition, there is apparently an overlap of two waves of the Internet shakeout, e.g., the tail end of the B2C wave is overlapping with the head-end of the broadly defined B2B trend.

Clearly, the Internet and its continued evolution will impact the future of the digital society. To meet these opportunities, a strong and stable economic environment is needed for e-commerce and other related information business activities as well as new and innovative technologies to create the broadband infrastructure and powering infrastructure required to provide individuals and businesses alike the opportunity to leverage the full potential of this digital economy.

Telecommunications and Networking

The ultimate functioning digital society is dependent upon all elements including microprocessor technology, Internet access, and telecommunication technologies working seamlessly. But as with many other systems, technologies tend to lag each other and manifest themselves in bottlenecks, so to speak. For instance, when the network was young, the bottleneck was the transmission speeds of end-user modems. Even though a web page might take a second or two to complete a transaction, this transaction speed was virtually invisible in the face of the several second lags inherent in the connection devices.

However, as the transmission technology evolves, bottlenecks get pushed farther and farther upstream, toward the end server. This places pressure on switching and server technologies until they are no longer the weak point and the problem is once again at the transmission end. And the cycle continues, while technologies strive to keep pace with each other.

Therefore the following gives a brief look at the evolution of telecommunication technologies and some future trends that will certainly have an impact on the digital economy as well.

Telecommunications

The first use of the term "telecommunication" was in 1973 by Jack Nilles, a rocket scientist working on a NASA satellite communications project in Los Angeles. Experiencing too many traffic gridlocks, Nilles decided to concentrate on moving work, not workers—thus started the idea of telecommunications from home to office. Now, in the Internet era, businesses are beginning to realize that to reap the maximum benefits of this digital era, they need to have high-speed, always-on Internet access on every laptop and desktop within their organization. As of the beginning of 2001, 88% of all connections to the Internet were at speeds of less than 53k, using dial-up modems and standard phone lines. But technology advances would soon make much greater speeds both affordable and viable.

The telecom industry demands speed and reliability. When it comes to telephone access, businesses and consumers alike expect to get essentially uninterrupted connectivity. The typical reliability required is "five nines," equating to 99.999 percent availability, considered the norm in the industry. These “five nines” translates into a mere five minutes of downtime per year.

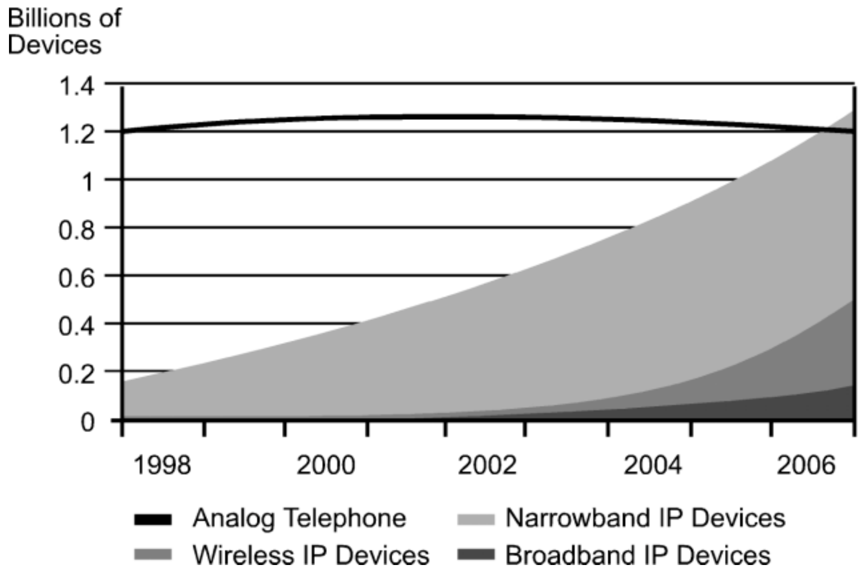


Figure 4-14
Future Trends for Growth of Telecom Devices

In the field of transmission, 90% of the fiber optic market will be driven mostly by business usage. Broadband communications has been one of the fastest growing markets in the telecommunications industry in the past couple of years. There were 3.49 million business users of broadband by 2000, and this figure is projected to reach 11.3 million by 2002 as small to medium enterprises (SMEs) exploit cheaper broadband access methods including DSL, Cable, and wireless broadband.

One popular method of broadband is the Cable Multiple System Operator (MSO) networks. Traditionally, MSOs provide one-way broadcast of video signals to homes and businesses. And, although cable MSOs continue to generate most of their revenue from video services, recently the interest has expanded to servicing data-over-cable and cable telephony services that offer significantly higher revenue opportunities.

The North American 2000-2004 market for standards-based cable modem products and services is estimated to be more than 20 million installed cable modem customers in North America by year-end 2004, up from 4.8 million at the end of 2000. Sales of Data Over Cable System Interface Specifications (DOCSIS) cable modems, cable modem termination system (CMTS), and IP switching equipment are projected to exceed $6 billion through 2004. Cable modem service revenue is projected to exceed $20 billion alone.

Cable Datacom News publisher Kinetic Strategies, Inc., estimated that there are 9.3 million residential broadband cable Internet subscribers in North America as of June 2001 (7.6 million in U.S. and 1.7 million in Canada), which equals to 8.2 percent household penetration by the cable service providers. However, Canada outranks the U.S. in the penetration of households with 15% vs. 7 %. Cable multiple system operators (MSOs) continue to dominate digital subscriber line (DSL) providers with an estimated 6.4 million cable modem customers in the U.S. and Canada, equal to 70 percent of the market. By comparison, DSL providers served 2.9 million residential subscribers.

Table 4-1
Residential Broadband Internet Market in North America, Source: June 2001, Kinetic Strategies, Inc.

	DSL	Cable	Total
Subscribers as of 6/1/01	2,913,636	6,450,916	9,364,552
Subscribers as of 3/31/01	2,543,938	5,800,103	8,344,041
Q1-01 Subscriber Additions	560,148	986,081	1,546,229
Q1-01 Average Adds/Week	43,088	75,852	118,941

Copper, coax, and fiber form a majority of the current distribution networks. With fiber recognized as the way of the future, more and more optical fibers are deployed each day. Current optical networks can carry slightly less than 2 Terabits/second of data per fiber strand. According to research published in July 2001, Bell Labs believes the theoretical limit of fiber can reach 100 terabits/second or about 20 billion one-page e-mails per fiber strand. These results prove that once fiber technology is fully utilized, a new era of speed and reliability will emerge.

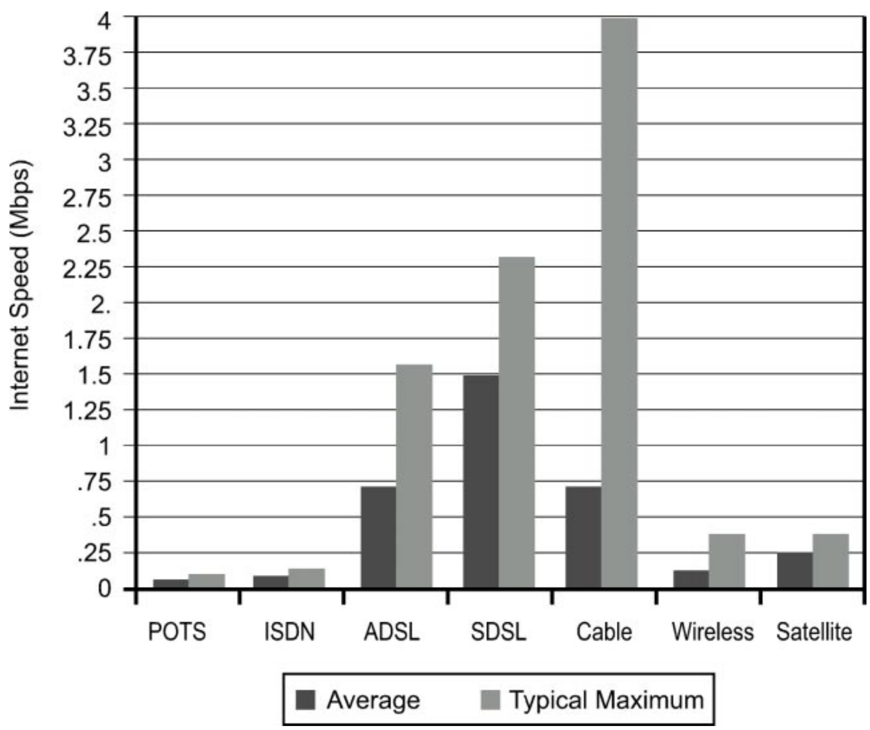


Figure 4-15
Typical Internet Speed Comparison

The figure above shows the typical Internet speeds offered by various technologies. While the dial-up service provided by the POTS (Plain Old Telephone System) is the slowest with the Internet speed of 56Kbps, DSL and Cable provide Internet speeds of 1.5Mbps and 4Mbps respectively, while the wireless and satellite data services can provide Internet speeds up to 384 Kbps.

Servers

A server is, in the strictest sense, a piece of software designed to handle requests from an outside party. In the hardware world, the word server can be used to refer to any system with a CPU that runs one or more server programs. These devices are usually made of higher quality components than regular personal computers in order to provide for a higher rate of availability since the non-stop role of these components requires them to function in a 24/7/365 manner with minimal downtime.

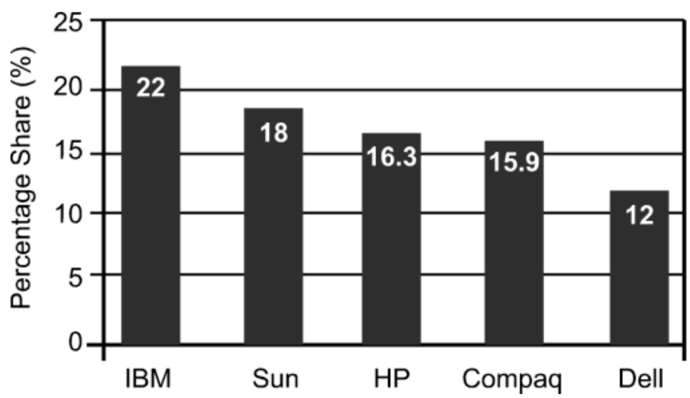


Figure 4-16
Top Five Server Manufacturers by Market Share in the U.S. (Source: http://www.idc.com/Hardware/press/PR/ES/GES061301pr.stm)

Some of the major manufacturers of servers are IBM, Dell, Sun, Gateway, Compaq, HP, Nokia, Resilience, Data General Corporation, and RLX Technologies. Though this is a competitive field, more than 80% of the market rests in the hands of the top five companies, which are IBM, Dell, Sun, Compaq, and HP. As innovations make their presences felt, smaller companies may get the chance to exploit the new opportunities generated to make their own place in the market.

Servers alone probably account for much of the inaccuracy in energy usage and data center power estimates. For instance, the figures mentioned in Table 4-2 below are for peak power consumption, and IDC designers, being conservative, would be more inclined to take peak numbers and then plan for those than to try to figure out what they would really need.

There is also the matter of empty rack space. Not all racks spend their time completely filled. This can make a big difference in the power density expected from the rack and, since most data center planning groups either do not anticipate low utilization or do not want to have to deal with adding additional capacity in the future, there is a tendency to over estimate in this sense, too.

Working for a more accurate estimate and one that is graduated over time would be the best manner in which to minimize the risky outlay of capital for an uncertain demand. Providing the right amount of power on the right time scale is to the advantage of both the utility and the data center.

Some general power consumption statistics for servers are:

- Typical power consumption: 150-200W for a 1U unit (1.75” tall)
- Maximum consumption: 300W/U

Floor Space and Power Density

The most significant aspect of a server is physical. In the past, most companies requiring servers would use a small number of powerful processors to get the job done. However, the current movement tends from a few expensive servers toward an array of less powerful, cheaper servers that are interchangeable and allow for another layer of redundancy. Supporting these additional servers means a growing demand for already premium floor space in the data center or computer room. To conserve this valuable space, the trend is toward rack-mounted servers.

Figure 4-17
HPj6000 Computer Farm (source: www.hp.com)

Servers that are intended to be rack-mounted are given a size rating in units of 1.75” (1U). One industry-standard, 2-meter rack often contains 42U of space, which could mean 40 or more in that rack. For instance, a rack fully loaded with 20 HP j6000s would have a maximum power density of 2kW-ft^2 (around 12kW in 23.5 in x 36.5 in or 5.96 ft^2). Of course, these racks do not account for all of the space inside IDCs or computer rooms, and rarely do maximum power figures translate into real power figures.

Additionally, though rack servers are among the most power-dense conventional servers out there, there are IDCs in areas where property values are relatively low and space is not quite so critical. These areas might see larger scale rooms with plenty of space for shelves to hold tower servers. Although the most powerful performance for a given volume of server is offered by a 1U or 2U server, many companies choose more bulky servers that have plenty of space for expanding storage and other necessities for which they would otherwise have to rent additional services or servers.

Figure 4-18
Server Blade (Left) and Server Blades in Chassis (Right) (Source: www.rlxtechnologies.com)

Though this kind of density is very powerful and is only now being fully realized in the industry, there are even more computationally dense schemes available now and in the future. Take, for example, the new RLX technologies System 324 server system. The servers are designed with "blade" architecture, a design that has been popular in telecom for years but had yet to make its presence felt in the computer industry. These blades fit into larger, 3U racks, which hold 24 blades, and can be rack mounted as normal. Each 3U unit has a power supply designed for 450 W, which is not as power dense as many other servers. Server blades are so thin that 336 of them can fit in the space of a standard 42U rack.

Table 4-2
Power Consumption of Various Rack Mount Servers

Company	Model	Power (W)	Size (U=1.75 inches)	Power/Size (W/U)
IBM	X Series 300	200	1	200
	X Series 330	200	1	200
Dell	Poweredge 350	125	1	125
	Poweredge 1550	240	1	240
	Poweredge 2550	330	2	165
Gateway	7450 r	200	1	200
	7250 r	275	2	137.5
Compaq	Proliant DL 320	180	1	180
	DL 360	190	1	190

	DL 380	275	3	97.7
	DL 580	450	4	112.5
HP	J6000	600	2	300
Sun Cobalt	RaQ 4	60	1	60
RLX Technologies	System 324 (24 server blades)	450	3	150

Server Trends

One of the most critical issues in digital applications and IDC facilities that exists today is how to expand capabilities and provide increased services without additional massive outlays of capital. Some centers will no doubt expand their current facilities, but others who neither can afford the time, space, or resources will look for innovative ways to better utilize their existing floor space. The answers to these issues will affect the way newer IDCs and other facilities may be constructed so as to optimize their floor space and reduce overall building costs.

Inside the current data center, there is a mixture of rack mounted, tower case, and mainframe style server equipment. Reassessing the old designs to provide for optimal space usage may require that a movement toward a more homogenous equipment mixture be undertaken. Each type of equipment has its own advantages and disadvantages, as well as a unique set of hurdles that must be overcome before a specific technology will emerge as the dominating one.

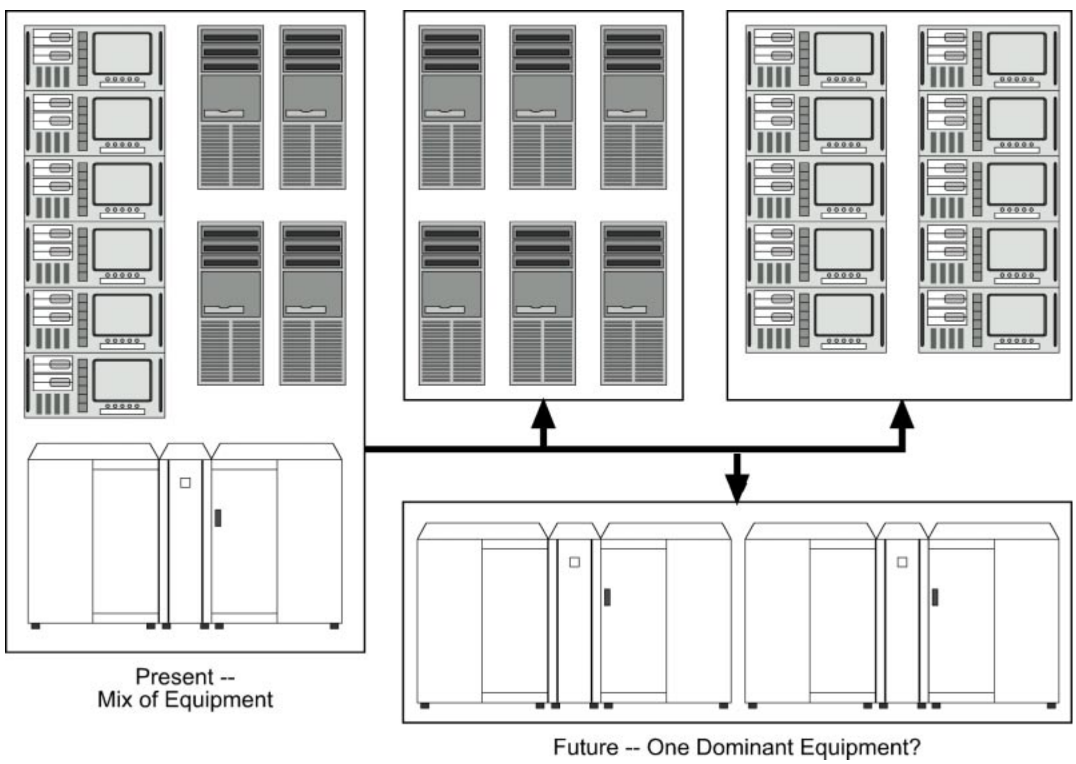


Figure 4-19
Possible Equipment Mixture Progression

Rack-Mounted Dominance

The current progression seems to indicate a move toward more and more rack-mounted servers. These are popular choices in IDCs because they offer greater scalability, computing power density, and redundancy than many other configurations. Being modular, rack servers offer what is probably the highest level of scalability and ease in physical arrangement. These are both big bonuses to an IDC that is looking at the possibility of needing to rearrange and expand the hardware allocations of customers on a regular basis. Also, the relatively low cost per unit and floor space requirements of these devices make it possible to maintain affordable redundancies for mission critical servers and applications.

However, this same advantage of rack-mounted servers somewhat limits their growth in the market. For instance, the current trend in processor powering is that greater processing power equals greater electrical power dissipation. Since rack servers are so computationally dense, cooling becomes a serious issue. As the power densities of server racks grow, it becomes necessary to rethink the cooling methods used to support them. Another issue with rack-mounted servers is the simple lack of space inside the server case for memory or storage upgrades, which can be comparably bulky. Improving the performance of a rack-mounted server often requires the replacement of the server with a faster one, or the addition of a load-sharing server.

Workstation or Tower Case Dominance

Workstations require considerably more floor space and, therefore, have inherent drawbacks. Tower servers offer excellent upgrade and provide ease of cooling system design due to the case size and the flexibility that it offers. These servers are, however, more expensive than rack servers and, thereby, are even more costly to provide necessary redundancies. Due to the relative ease with which an older tower server can be upgraded, component by component, often various parts of the tower server remain in use longer than ideal. This, in turn, degrades the reliability of the system as opposed to the entire system being replaced.

These types of servers are likely to remain popular in certain applications, where a large amount of processor power is needed in a single machine, or when case upgrades are needed, but they are not likely to dominate IDCs as a whole.

Mainframe Dominance

Few companies possess the capital to purchase mainframe systems, or even have a legitimate need for one. Mainframes are very large, often taking up an entire computer room for a single machine, and quite costly both to purchase and maintain. Traditionally, the primary users of these systems were groups that had a need for the larger computing capacity.

However, with new virtual server schemes, or schemes by which a mainframe computer is, in fact, divided up internally in such a way as to appear to be several smaller servers from the outside, may be able to change all that. A complicated piece of software runs on the mainframe and divides its functions up into many individual “server spaces” that can then be allocated to resources according to need or priority. Larger companies can buy these mainframes and then sell the “virtual” space on them just as space on regular servers has been sold in the past. Doing so actually makes good business sense since a single mainframe can host a thousand or more virtual servers at a fraction of the cost and size of many servers. This would allow even smaller customers access to the processing power of a mainframe, as well as provide an affordable alternative to actual server rental.

In addition, there are some secondary benefits. Since the mainframe is not likely to change in composition and is typically stationary, dedicated cooling topologies, which are generally more efficient and easier to maintain, can be utilized versus the more generalized cooling systems, which often do not function at peak efficiency.

Initial costs of these mainframe systems will continue to be the biggest barriers for wide use and application. In addition, redundancy options are also limited. Maintaining a spare mainframe is not likely to be an option for most operations and even mirror sites may be prohibitively expensive, especially if only a portion of the customers on the mainframe desire a mirror.

Lastly, utilizing mainframes for multiple customer applications increases security issues, which might outweigh the advantages of lower per unit cost associated with such schemes. Since multiple users' data would be on the same machine, there is a higher risk or vulnerability to breaching the onsite security of another company.

New Equipment Dominance

While the previous trends assume that the current "big three" types of server remain the main options available, it is possible that an entirely new server technology will take hold and dominate the market place. One example of such a technology is the blade server noted in the section above. Right now, only one company is producing these compact new devices, but at least three of the top five server producers in the U.S. already have plans to introduce their own versions of this new technology. Even compared to the most state-of-the-art rack server, blade servers offer more computing power in a smaller package for less electrical power density. The emergence of such new technologies is, perhaps, one of the greatest "wild card" factors in the industry, even more so in the computer industry than many other industries due to the rapid life cycles of new product development.

Internet Connectivity Trends

So, what are the factors in selecting how an individual will connect to the processing power behind the Internet service provider? End-users are typically driven by three factors: speed, reliability, and cost. Most customers will emphasize one over the others, but all three factors are usually considered before a choice is made. Each technology has its own unique set of specifications that make it more or less likely to see some dominance and future growth.

Dialup Modems

The basic dialup modem, the staple of connection, has undergone some advances since the inception of the Internet, but has reached its limitations. In the future, the dialup modem will likely continue to be the method of choice for new users who either are not well versed in the other technologies or wish to select the least expensive option. As the need and desire for increased speeds escalates, these modems may eventually become obsolescent.

ISDN

Integrated Services Digital Network (ISDN) is also a technology that has reached its peak, for the most part. While the benefits it offers are still valid, such as no installation and only a marginally more expensive piece of user end equipment required, the relative cost per value in increased speed is marginal compared to some of the other newer technologies being offered.

Cable and DSL

Cable, while not exactly new technology, is one that is poised to take off in the near future. The commonality of cable lines alone makes this a popular choice since it requires little installation work, and, in fact, can be installed by the end user with little trouble. The speeds are much greater than ISDN or dialup, and in the future, as the copper cable head end is shortened and fiber carries the signal farther, the speeds will only increase, even with much greater traffic levels.

Digital Subscriber Line (DSL) technology, as with cable modems, is anticipated to increase in popularity. One of the IDC reports estimates that subscribers to the high-bandwidth connection will increase by 71 percent from 4.5 million in 2001 to 7.7 million in 2002 and projected to be 16.5 million by 2004. The In-Stat Group[45] believes that DSL will prove to be more popular than cable modem or satellite services within a few years. Recent developments, such as falling modem prices, reduced service charges, and technological developments, may encourage consumers to choose DSL over its rivals. Although cable modem broadband access has taken an early lead over DSL adoption, DSL is poised to overtake cable modem access by 2003, with a projected 14.2 million subscribers. Regardless of the market share, DSL and Cable will constitute approximately two-thirds of all broadband deployment. The figure below gives a projection of the growth of the DSL technology in US.

[45] The In-Stat Group, http://www.instat.com/

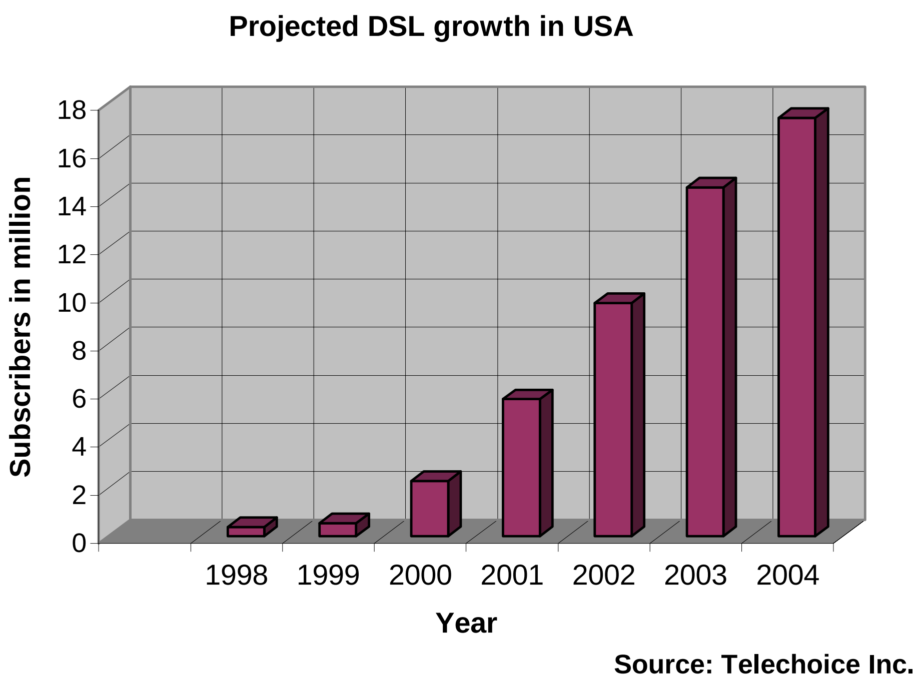


Figure 4-20
Projected DSL Growth in the U.S.

Sprint ION Systems

Sprint ION[SM] (Integrated On-demand Network) is a breakthrough technology that lets a user attach simultaneously to voice, data, video, Internet/intranet, and fax applications to the Sprint high-speed network over a single connection. It supports local and long-distance telephony and can eliminate the need for multiple voice and data networks. Not only does it reduce the management costs, but it also maximizes the efficiency of the network utilization. Sprint ION dynamically and equitably shares available bandwidth between competing traffic so that critical applications are assigned the performance characteristics they need while maintaining the integrity of other applications.

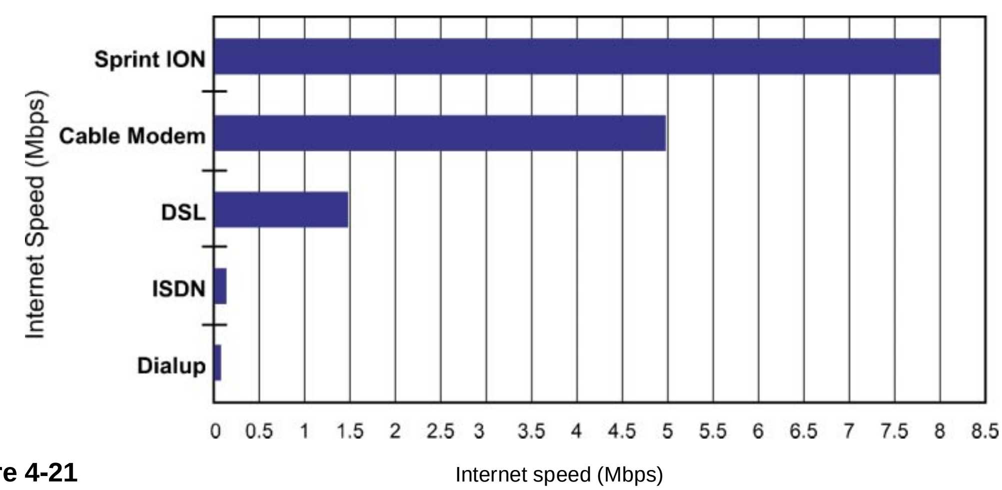


Figure 4-21
Comparison of Internet Downstream Speeds of Existing Types with Sprint ION Technology (Source: www.sprint.com)

Sprint ION technology can provide a downstream speed of 8Mbps, an upstream speed of 1Mbps, which is 142x faster than the traditional dial-up services. The following figures (Figure 4-22 and Figure 4-23) shows how the traditional network environment can be modified by the Sprint ION system.

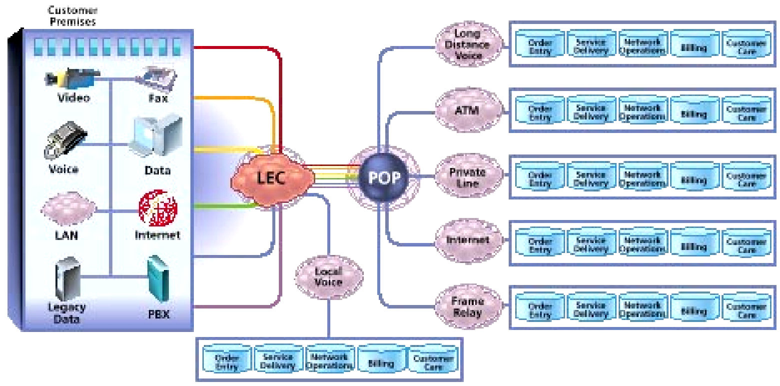


Figure 4-22
Traditional Network Environment (Source: www.sprint.com)

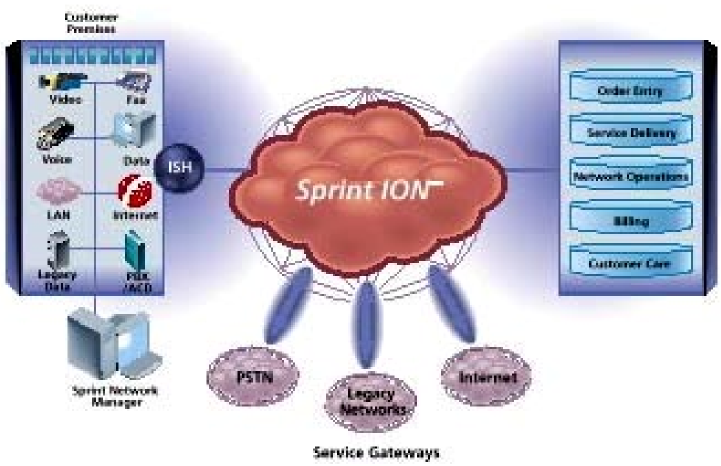


Figure 4-23
Converged Network Environment Offered by Sprint ION System

Sprint ION can give telecommunication users new levels of control over their network resources and enable them to deploy new services and applications more rapidly than before. Converged network services allow applications to determine how to use the network instead of the network limiting which applications can be offered. Thus with a fully converged network like Sprint ION, businesses can leverage the advantages of a ubiquitous broadband network to revamp their business processes and enrich their bottom lines.

Wireless Trends

Wireless technology has already progressed through two distinct stages of evolution. First-generation (1G) wireless technology used analog signals to send communications between two points. This lasted until the 1990s when second-generation (2G) protocols became available. The 2G offered digital encoding and added clarity. Because its inception, there has been a steady increase in the bandwidth, packet routing, and multimedia abilities of the technology, which is still in use today and is often referred to as 2.5G wireless.

Third-generation wireless (3G) is due to be commercially available sometime between 2003 and 2005 and will boast extended multimedia, speed, and portability capabilities. Unlike 2G, which used different protocols in different parts of the world, 3G is planned to use a single standard that will be universal between the United States, Europe, Asia, and the world as a whole. In theory, 3G phones will one day be usable from anywhere in the world through their use of satellite receivers as well as more mundane terrestrial receivers.

Universal Mobile Telecommunications Service (UTMS) is the current favorite for a universal 3G protocol. Widely researched in Europe, it has been settled on by many organizing bodies to be the new standard.

As wireless protocols advance into their third generation, it is likely that they will become much more prevalent. For instance, IDC predicts there will be more wireless than wire-line users accessing the Internet in 2003. Further, IDC estimates that there are more than 75 million cellular subscribers and over 40 million paging subscribers in the U.S., compared with only 40 million U.S. households online, and projects that by the end of 2001, all digital cellular handsets shipped in the world will be capable of accessing the Internet. Because of this trend, analysts predict that there will be a shift in the way the Internet is developed. Web designers and writers will begin to build WAP-enabled (Wireless Access Protocol) pages to be read on wireless devices, rather than on full-screen monitors.

The Internet can also be accessed through two-way pagers. Such services allow users to set up accounts and establish preferences for information on various topics including stocks, weather, lottery, and horoscopes. The information is sent to the pagers on demand from WAP-enabled websites. BellSouth recently announced that it will upgrade the service of its Internet-enabled pagers to include access to Microsoft Exchange server based applications such as calendars and contacts, and to give users pager-to-pager communications links for workgroup applications.

Handheld devices, also referred to as personal digital assistance devices (PDAs), have larger screens than pagers. The most popular PDA is the Palm Pilot. The latest version has wireless Internet access in addition to its traditional features. Similarly, web-enabled cell phones offer time- and location-sensitive information such as movie times and restaurant listings, as well as email capabilities. In the near future, experts expect cell phones to be equipped with foldout keyboards, eyepieces, and color displays, and may incorporate features such as speech recognition.

Wireless laptops offer large screens and keyboards to business users, but may be less popular consumer devices because of their size. In addition, laptops only offer Internet access in limited locations at limited speeds. CDPD (Cellular Digital Packet Data), one of the technologies used for wireless laptop connections, can be used anywhere there is cellular telephone coverage, which now includes most metropolitan areas. Data transmission speeds are at about 14.4 Kbps to 19.2 Kbps, much slower than a 56 Kbps modem, but speeds are expected to increase in the very near future.

Other wireless technologies, such as Bluetooth and IEEE 802.11, allow users wireless Internet connections, but greatly limit the user by distance. For example, Bluetooth only works within about 32 feet of the network. The development of wireless Internet connection via satellite is still in its infancy. However, on June 12, 2001, Juno Online Services and Hughes Network Systems announced plans to offer high-speed Internet access via satellite to consumers living virtually anywhere in the U.S. Users will have downstream access speeds up to 400 Kbps, but users will have to send data upstream by using a standard modem and phone line. The companies plan to offer full two-way satellite Internet access by 2001. Subscribers of this satellite service will need to install a satellite dish and a satellite-compatible modem.

A different wireless standard is called 802.11b and is pronounced “eight oh two dot eleven bee.” However, many are advocating a friendlier name, Wi-Fi, for wireless fidelity. Currently, Apple manufactures all of their new laptops for 802.11b and other manufacturers are following suit. An installed base station on a home network will enable users to carry laptops from room to room, basement to kitchen counter, and never go off line. Wi-Fi is “the next big thing,” asserts J. William Gurley, a Menlo Park, California, venture capitalist and online columnist. “The history of technology has proven again and again that if a certain open architecture gains escape velocity, there is no turning back.” So whether it is 802.11b or Bluetooth or a combination of those and something else besides, it appears there is no turning back.

The 3G technologies offer wireless Internet access at rates of 384 Kbps or higher. Migration to full 3G offers mobile professionals the ability to access data as if they were connected to their office LAN. The 3G technologies will enable the use of wireless multimedia and video applications, as well as video conferencing. Remote video monitoring will also be possible. For example, a mobile 3G device will be able to display the various views from several cameras placed around a facility or home.

In June 2001, AT&T Wireless Services teamed with Nortel Networks to begin testing 3G technologies for wireless Internet devices. The International Telecommunications Union has approved 3G as a wireless technology standard. The technology is ultimately expected to allow AT&T customers to have wireless coverage with access to high data transmission speeds anywhere in the world. Universal Mobile Telecommunications Service (UTMS) is the current favorite for a universal 3G protocol. Widely researched in Europe, it has been settled on by many organizing bodies to be the new standard.

Most analysts agree that wireless Internet devices will be commonplace in the near future. However, a recent study from Forrester Research found that, today, only 8 percent of customers who own digital cell phones are interested in receiving mobile data services. In addition, consumers must understand that Internet access through wireless devices is still not exactly the same as surfing the web at home. The data displayed is much more text based. Before wireless data is in strong demand, a few changes in the market must take place. Consumers will demand higher bandwidth and lower prices. They will also demand more content, personalized and convenient services, and wireless devices that are comfortable to handle and easy to use. However, once services improve and prices decrease, the wireless data market is expected to explode.

Implications

Without question, the digital revolution is reshaping the computing, communication, and traditional business landscape, and this new worldwide economy presents not only tremendous opportunities, but also challenges for all stakeholders including utilities, energy providers, manufacturers, end-users, and governmental organizations. There is an imperative for all stakeholders to work collaboratively to be appropriately prepared and equipped to embrace these challenges that the digital economy will invariably bring. And although each stakeholder may have individual motivating factors, the fact remains that all the stakeholders are interlinked from energy service provider to end user through the engine that drives digital technology—that is electricity.

This digital society enabled through advances in microprocessor technology will also continue to provide improvements and increases in connectivity, productivity, and efficiency. The evidence of digital is everywhere—in our homes, offices, and factories—and will, no doubt, change the fabric of our lives and will bring far-reaching implications. "The average American house already contains more than 40 computers embedded in various items. A typical electric toothbrush runs on about 3,000 lines of code. Last year (2000) alone, 8 billion new microprocessors came into the world."[46] And the implications do not stop there. For instance, the Internet makes possible what might be called e-materialization. According to Joseph Romm, Executive Director, Center for Energy and Climate Solutions Subcommittee on National Economic Growth, Natural Resources and Regulatory Affairs of the Committee on Government Reform House of Representatives, by 2003, e-materialization of paper alone holds the prospect of cutting energy consumption by about 0.25% of total industrial energy use and net GHG emissions by a similar percentage. By 2008, the reductions are likely to be more than twice as great. It is also believed that the Internet Economy could render unnecessary as much as 3 billion square feet of buildings—some 5% of U.S. commercial floor space—which would likely save a considerable amount of construction-related energy. By 2010, e-materialization of paper, construction, and other activities could reduce U.S. industrial energy and GHG emissions by more than 1.5%.

Another economic gain associated with the digital era is in the overall efficiency gains of product inventories. In fact, Alan Greenspan, chairman of the Federal Reserve Board, believes that the efficiency gains of electronic commerce could lead to a drop in overall product inventories of $250 billion to $300 billion a year—a reduction of as much as 30% in the country's inventory levels.

On the industrial front, the digital society allows for great opportunities in other productivity enhancements. For example, an eFoundry has been established by Taiwan Semiconductor Manufacturing Company (TCMS), founded in 1987. With annual sales of US$5.3 billion in 2000 and currently employing over 14,500 people worldwide, TCMS serves and supports customers' manufacturing needs by maintaining account service offices in Taiwan, North America, Europe and Japan. The development of e**F**oundry allows their customers 24/7 online access to engineering information and electronic supply chain information such as purchase orders, work-in-process reports, shipping notices, and other important logistical information. Customers also have access to yield analysis services, order status, backlog, and wafer sort, QA, SPC data, and process reliability data monitoring thereby improving productivity and efficiency through this creative use of digital technologies. (http://www.tsmc.com.tw/efoundry/index.html)

On yet another front, advances in microprocessors and associated technologies just might afford this country and the world an improved standard of living while still conserving natural

[46] James Gleick, *Connected: Life in the Wireless Age*

resources. For instance, Alex Lidow, CEO of International Rectifier, anticipates that a $119 billion savings in energy conservation could be realized through a complete conversion to compact fluorescent lighting and another $72 billion from installation of semiconductor-based drives on motor systems.[47] These statistics provide some basis that, although digital loads are increasing in percent of total electrical loads, this does not necessarily imply increased electrical consumption.

Table 4-3
Potential Savings Through Use of Advanced Power Conversion Technologies[48]

AC/DC Conversion Technologies						
Power Range (Watts)	150	300	500	750	1,000	Total
Average Watts	45	175	335	625	800	
Millions of Units	276	106	34	11	8	
Aggregate electric power (MW)	12,442	18,580	11,238	6,968	6,097	55,325
DC/DC Conversion Technologies						
Power Range (Watts)	50	100	150	250	500	
Average Watts	25	50	75	125	250	
Millions of Units	28	17	8	8	3	
Aggregate electric power (MW)	700	871	609	995	726	3,901
					Total MW	59,226

Always on, improved productivity, and increased energy efficiency—these are the fruits of the digital era and what society will come to expect and demand. But the challenges are many that face utility service providers and end-users alike to better understand what is digital and how to support it with a sustainable electrical infrastructure.

[47] Alex Lidow, CEO, International Rectifier, *The Power Conversion Process as a Prosperity Machine, Part II — Power Semiconductor Road Maps,* March 16, 1999.

[48] Alex Lidow, CEO, International Rectifier, *The Power Conversion Process as a Prosperity Machine, Part II — Power Semiconductor Road Maps,* March 16, 1999.

APPENDICES

A

CENSUS BUREAU INFORMATION FOR CLASS 1: COMMUNICATIONS/WHOLESALE AND RETAIL COMPUTER, SOFTWARE, INDUSTRIAL MACHINERY

SIC	NAICS	Pt	Description	Establish-ments	Revenue ($1,000)	Paid employees	Annual payroll ($1,000)
481	97/92		Telephone	28,783	256,130,797	999,954	46,899,659
4812			Radiotelephone	6,497	38,271,339	147,845	5,950,128
	513321		Paging	3,427	16,970,204	70,445	2,583,708
99% of	513322	Σ	Cellular & other wireless telecommunications	2,712	20,661,622	65,193	3,190,306
	513322	10	Cellular telephone service	2,261	19,055,624	65,193	2,726,368
	513322	20	Specialized (smr) & other mobile radio services	451	1,605,998	8,297	463,938
8% of	513330	10	Resellers - cellular or other wireless service	358	639,513	3,910	176,114

SIC	NAICS	Pt	Description	Establish-ments	Revenue ($1,000)	Paid employees	Annual payroll ($1,000)
4813			Other telephone	22,286	217,859,458	852,109	40,949,531
100% of	513310	10	Wired telecommunications carriers - local & long-distance	20,632	208,612,981	813,944	39,513,278
92% of	513330	20	Resellers - wired telephone service	1,298	6,952,785	26,118	1,008,964
60% of	561421	20	Voice mailbox	356	2,293,692	12,047	427,289
482	97/92		Telegraph communications	183	177,571	1,483	51,262
4822			Telegraph communications	183	177,571	1,483	51,262
0% of	513310	20	Wired telecommunications carriers - telegraph service	183	177,571	1,483	51,262
483	97/92		Radio and television broadcasting	8,789	40,425,210	249,715	9,868,917
4832			Radio broadcasting	6,894	10,648,134	126,673	3,604,481
	513111		Radio networks	303	851,348	5,648	216,563
	513112		Radio stations	6,591	9,796,786	121,025	3,387,918
4833			Television broadcasting	1,895	29,777,076	123,042	6,264,436
	513120		Television broadcasting	1,895	29,777,076	123,042	6,264,436

SIC	NAICS	Pt	Description	Establish-ments	Revenue ($1,000)	Paid employees	Annual payroll ($1,000)
5045			Computers & computer peripheral equipment & supplies	19,753	239,604,341	348,435	18,409,294
100% of	421430	Σ	Computer & computer peripheral equipment & software whsle	16,929	221,447,412	91,857	17,305,512
	421430	11	Computers & peripheral equipment for resale	5,657	115,317,362	91,857	4,275,564
	421430	12	Computers & peripheral equipment for end use	8,423	94,443,443	190,478	11,174,448
	421430	20	Computer software whsle	2,849	11,686,607	35,327	1,855,500
24% of	443120	Σ	Computer & software stores	2,808	5,753,655	21,176	794,291
	443120	22	Computer & peripheral equipment merchants (retail)	2,472	5,130,428	21,176	649,863
	443120	32	Computer software merchants (retail)	336	623,227	3,382	144,428
16% of	454110	50	Nonstore computer & peripheral equipment merchants	16	12,403,274	6,215	309,491
5084			Industrial machinery & equipment	33,444	131,684,528	315,416	13,073,826
94% of	421830	Σ	Industrial machinery & equipment whsle	33,444	131,684,528	12,098	13,073,826
	421830	10	Food-processing machinery & equipment whsle	1,333	4,273,371	12,098	496,582
	421830	21	Hydraulic & pneumatic pumps & motors whsle	1,636	4,753,826	13,756	543,359

SIC	NAICS	Pt	Description	Establish-ments	Revenue ($1,000)	Paid employees	Annual payroll ($1,000)
	421830	30	General-purpose industrial machinery & equipment whsle	11,101	42,641,534	102,295	4,279,378
	421830	40	Metalworking machinery & equipment whsle	4,092	19,008,973	35,524	1,603,844
	421830	50	Materials handling equipment whsle	4,642	18,803,215	63,169	2,371,197
	421830	60	Oil well, oil refinery, & pipeline mach, equip, & supplies whsle	3,536	11,671,958	25,475	1,006,985
	421830	70	Other industrial machinery & equipment whsle	7,104	30,531,651	63,099	2,772,481

Manufacturing of Digital Equipment

SIC	NAICS	Pt	Description	Establish-ments	Value of Shipments ($1,000)	Paid employees	Annual payroll ($1,000)
357			Computer and office equipment	2,181	D	(100,000+)	D
3571			Electronic computers	563	66,331,909	100,115	4,282,451
	334111		Electronic computer mfg	563	66,331,909	100,115	4,282,451
3572			Computer storage devices	211	13,907,367	42,364	1,950,230
	334112		Computer storage device mfg	211	13,907,367	42,364	1,950,230
3575			Computer terminals	142	1,483,460	5,764	253,087

SIC	NAICS	Pt	Description	Establish-ments	Value of Shipments ($1,000)	Paid employees	Annual payroll ($1,000)
	334113		Computer terminal mfg	142	1,483,460	5,764	253,087
3577			Computer peripheral equipment, n.e.c.	1,006	25,130,308	87,253	4,337,970
93% of	334119	10	Other computer peripheral equipment mfg (pt)	1,006	25,130,308	87,253	4,337,970
3578			Calculating & accounting equipment	96	2,014,806	7,683	275,962
5% of	333313	10	Office machinery mfg (pt)	35	144,380	966	30,889
7% of	334119	20	Other computer peripheral equipment mfg (pt)	61	1,870,426	6,717	245,073
3579			Office machines, n.e.c.	163	D	(10k-24999)	D
96% of	333313	20	Office machinery mfg (pt)	134	3,047,549	13,865	427,315
D	334518	20	Watch, clock, & part mfg (pt)	16	D	(500-999)	D
21% of	339942	20	Lead pencil & art good mfg (pt)	13	257,020	1,234	30,572
365	97/92		Household audio and video equipment	834	10,699,568	48,325	1,438,451
3651			Household audio & video equipment	554	8,454,194	31,727	944,647
	334310		Audio & video equipment mfg	554	8,454,194	31,727	944,647
3652			Prerecorded records & tapes	280	2,245,374	16,598	493,804
58% of	334612	10	Prerecorded CD (except software), tape, & record	280	2,245,374	16,598	493,804

SIC	NAICS	Pt	Description	Establish-ments	Value of Shipments ($1,000)	Paid employees	Annual payroll ($1,000)
			reproducing (pt)				
366			Communications equipment	2,213	80,949,148	283,751	13,272,409
3661			Telephone & telegraph apparatus	625	39,673,619	110,408	5,591,933
	334210		Telephone apparatus mfg	598	38,300,044	104,262	5,329,203
1% of	334416	10	Electronic coil, transformer, & other inductor mfg (pt)	7	8,904	63	1,836
5% of	334418	10	Printed circuit assembly (electronic assembly) mfg (pt)	20	1,364,671	6,083	260,894
3663			Radio & TV communications equipment	1,091	37,042,241	148,156	6,765,352
94% of	334220	10	Radio & TV broadcasting & wireless communications equipment mfg (	1,091	37,042,241	148,156	6,765,352
3669			Communications equipment, n.e.c.	497	4,233,288	25,187	915,124
	334290		Other communications equipment mfg	497	4,233,288	25,187	915,124
367			Electronic components and accessories	6,605	141,997,578	611,693	22,958,642
3671			Electron tubes	159	3,858,499	21,976	742,074
	334411		Electron tube mfg	159	3,858,499	21,976	742,074
3672			Printed circuit boards	1,401	9,787,576	76,702	2,313,578

SIC	NAICS	Pt	Description	Establish-ments	Value of Shipments ($1,000)	Paid employees	Annual payroll ($1,000)
	334412		Bare printed circuit board mfg	1,401	9,787,576	76,702	2,313,578
3674			Semiconductors & related devices	1,099	78,539,562	199,497	10,112,757
	334413		Semiconductor & related device mfg	1,099	78,539,562	199,497	10,112,757
3679			Electronic components, n.e.c.	2,925	38,938,113	226,262	7,321,800
6% of	334220	20	Radio & TV broadcasting & wireless communications equipment mfg (	126	2,265,873	16,305	606,528
95% of	334418	20	Printed circuit assembly (electronic assembly) mfg (pt)	695	24,704,154	104,971	3,582,172
	334419		Other electronic component mfg	1,851	10,547,090	92,200	2,769,216

KEY

N = Comparable data not available; D = Withheld to avoid disclosure

Σ = Sum of NAICS parts listed below the symbol

97/92 = Links to Comparative Statistics for 1992 and 1997

	(Bridge complete.)	Comparable	SIC derivable from NAICS data.
	(Drawbridge slightly open.)	Almost comparable	Sales or receipts from NAICS are within 3% of SIC sales or receipts.

	(Drawbridge open.)	Not comparable	SIC sales or receipts cannot be estimated within 3% from NAICS data.

B
U.S. CENSUS BUREAU INFORMATION FOR CLASS 2

SIC	NAICS	Pt	Description	Establish-ments	Value of Shipments ($1,000)	Paid employees	Annual payroll ($1,000)
354	97/92		Metalworking machinery	11,706	39,692,950	296,489	11,812,262
3541			Machine tools, metal cutting types	393	5,183,521	28,849	1,241,372
97% of	333512	10	Machine tool (metal cutting types) mfg (pt)	393	5,183,521	28,849	1,241,372
3542			Machine tools, metal forming types	225	2,255,011	14,185	598,606
	333513		Machine tool (metal forming types) mfg	225	2,255,011	14,185	598,606
3566			Speed changers, drives, & gears	268	2,402,392	16,231	597,248
	333612		Speed changer, industrial high-speed drive, & gear mfg	268	2,402,392	16,231	597,248
3632			Household refrigerators & freezers	27	4,887,364	24,597	801,717
	335222		Household refrigerator & home freezer mfg	27	4,887,364	24,597	801,717
3645			Residential lighting fixtures	497	2,177,355	16,395	406,444

SIC	NAICS	Pt	Description	Establish-ments	Value of Shipments ($1,000)	Paid employees	Annual payroll ($1,000)
97% of	335121	20	Residential electric lighting fixture mfg (pt)	497	2,177,355	16,395	406,444
3646			Commercial lighting fixtures	356	4,047,437	23,090	657,341
	335122		Commercial/industrial/institutional electric lighting fixture mfg	356	4,047,437	23,090	657,341
3648			Lighting equipment, n.e.c.	327	3,054,806	18,274	541,183
100% of	335129	10	Other lighting equipment mfg (pt)	327	3,054,806	18,274	541,183

SIC	NAICS	Pt	Description	Establish-ments	Value of Shipments ($1,000)	Paid employees	Annual payroll ($1,000)
382	97/92		Measuring and controlling devices	4,787	46,449,122	263,237	11,037,829
3823			Process control instruments	1,002	7,890,923	49,196	2,004,259
	334513		Industrial process control instrument mfg	1,002	7,890,923	49,196	2,004,259
3825			Instruments to measure electricity	843	13,877,200	63,522	3,008,675
2% of	334416	30	Electronic coil, transformer, & other inductor mfg (pt)	17	24,303	190	6,985
	334515		Electricity measuring & testing instrument mfg	826	13,852,897	63,332	3,001,690
3826			Analytical instruments	664	7,157,038	38,200	1,782,600
100% of	334516	20	Analytical laboratory instrument mfg (pt)	664	7,157,038	38,200	1,782,600
3827			Optical instruments & lenses	495	3,174,652	20,801	833,784
100% of	333314	20	Optical instrument & lens mfg (pt)	495	3,174,652	20,801	833,784

3829			Measuring & controlling devices, n.e.c.	859	5,176,695	34,425	1,373,655
100% of	334519	20	Other measuring & controlling device mfg (pt)	853	5,114,547	33,904	1,356,368
0% of	339112	10	Surgical & medical instrument mfg (pt)	6	62,148	521	17,287
384	97/92		Medical instruments and supplies	4,818	D	(100,000+)	D
3841			Surgical & medical instruments	1,598	18,450,024	107,298	4,139,100
100% of	339112	20	Surgical & medical instrument mfg (pt)	1,598	18,450,024	107,298	4,139,100
3842			Surgical appliances & supplies	1,728	D	(50k-99999)	D
D	322121	30	Paper (except newsprint) mills (pt)	2	D	(250-499)	D
7% of	322291	20	Sanitary paper product mfg (pt)	16	651,398	2,236	68,411
7% of	334510	20	Electromedical & electrotherapeutic apparatus mfg (pt)	74	807,427	6,722	224,883
96% of	339113	20	Surgical appliance & supplies mfg (pt)	1,636	14,743,779	82,390	2,865,055
3843			Dental equipment & supplies	877	2,699,867	18,072	613,286
100% of	339114	20	Dental equipment & supplies mfg (pt)	877	2,699,867	18,072	613,286
3844			X-ray apparatus & tubes	155	3,942,256	14,276	664,233
	334517		Irradiation apparatus mfg	155	3,942,256	14,276	664,233
3845			Electromedical equipment	460	10,567,566	47,121	2,372,703
92% of	334510	30	Electromedical & electrotherapeutic apparatus mfg (pt)	460	10,567,566	47,121	2,372,703

5047			[Medical, dental, & hospital equipment & supplies]	11,013	60,278,233	131,501	6,056,969
100% of	421450	Σ	Medical, dental, & hospital equipment & supplies whsle	9,782	58,791,711	106,502	5,746,165
	421450	10	Surgical, medical, & hospital supplies whsle	8,721	54,484,063	106,502	5,125,079
	421450	20	Dental equipment & supplies whsle	1,061	4,307,648	15,070	621,086
31% of	446199	20	Surgical, medical, & hospital supplies stores (retail)	1,231	1,486,522	9,929	310,804
5075			Warm air heating & air-conditioning equipment & supplies	5,524	20,062,710	51,252	2,013,489
	421730		Warm air heating & air-conditioning equipment & supplies whsle	5,524	20,062,710	51,252	2,013,489
5078			Refrigeration equipment & supplies	1,572	5,135,271	13,131	517,245
	421740		Refrigeration equipment & supplies whsle	1,572	5,135,271	13,131	517,245

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97/92 I= Links to Comparative Statistics for 1992 and 1997

	(Bridge complete.)	Comparable	SIC derivable from NAICS data.
	(Drawbridge slightly open.)	Almost comparable	Sales or receipts from NAICS are within 3% of SIC sales or receipts.
	(Drawbridge open.)	Not comparable	SIC sales or receipts cannot be estimated within 3% from NAICS data.

C
U.S. CENSUS BUREAU INFORMATION FOR CLASS 3 (CREDIT INSTITUTIONS, BUSINESS SERVICES, TELEVISION & COMPUTER SERVICES)

SIC	NAICS	Pt	Description	Establish-ments	Revenue ($1,000)	Paid employees	Annual payroll ($1,000)
484	97/92		Cable and other pay television broadcasting	4,679	45,389,578	174,351	6,151,186
4841			Cable & other pay television broadcasting	4,679	45,389,578	174,351	6,151,186
	513210		Cable networks	494	10,389,609	26,488	1,358,211
	513220		Cable & other program distribution	4,185	34,999,969	147,863	4,792,975
5734			Computer & computer software stores	8,933	18,305,008	65,943	1,483,473
76% of	443120	Σ	Computer & software stores	8,933	18,305,008	17,013	1,483,473
	443120	10	Computer stores (custom assembly)	3,801	3,983,465	17,013	395,184
	443120	21	Computer stores	3,198	12,100,010	37,416	815,782
	443120	31	Computer software stores	1,934	2,221,533	11,514	272,507
615	97/92		Business credit institutions	4,981	55,754,100	112,885	5,766,636
6153			Short-term business credit institutions, except agricultural	2,688	28,357,177	71,823	3,373,069
12%	522210	90	Other short-term business credit	73	2,870,040	9,682	331,178

SIC	NAICS	Pt	Description		Establish-ments	Revenue ($1,000)	Paid employees	Annual payroll ($1,000)
of			institutions					
20% of	522220	30	Commercial finance companies		1,675	15,451,473	27,002	1,531,193
21% of	522298	40	Factors		712	3,489,561	10,824	533,640
19% of	522320	30	Credit card service by business credit institutions		228	6,546,103	24,315	977,058
6159			Miscellaneous business credit institutions		2,293	27,396,923	41,062	2,393,567
29% of	522220	90	Financing leases		1,737	22,965,277	33,491	1,990,821
0% of	522292	20	Farm mortgage companies		14	7,353	55	2,776
17% of	522293	90	International trade credit		63	511,737	569	32,839
3% of	522294	90	Secondary market financing		174	1,506,869	2,563	125,832
15% of	522298	Σ	All other nondepository credit intermediation		305	2,405,687	458	241,299
	522298	50	Agricultural credit (except federally-sponsored)		68	197,415	458	16,723
	522298	90	Other miscellaneous business credit institutions		237	2,208,272	3,926	224,576
737	97/92		Computer programming, data processing, and other computer related services	Taxable	103,278	224,114,386	1,420,769	75,805,437
7371			Computer programming services	Taxable	31,624	38,300,515	318,198	18,417,084
	541511		Custom computer programming services	Taxable	31,624	38,300,515	318,198	18,417,084
7372			Software publishers	Taxable	12,090	61,699,420	266,380	18,386,784

SIC	NAICS	Pt	Description		Establish-ments	Revenue ($1,000)	Paid employees	Annual payroll ($1,000)
	511210		Software publishers	Taxable	12,090	61,699,420	266,380	18,386,784
7373			Computer systems integrators	Taxable	10,571	35,270,055	207,741	11,341,975
69% of	541512	10	Computer systems integrators	Taxable	10,571	35,270,055	207,741	11,341,975
7374			Data processing services	Taxable	7,588	30,836,645	262,250	9,773,857
	514210		Data processing services	Taxable	7,588	30,836,645	262,250	9,773,857
7375			On-line information services	Taxable	4,165	8,042,568	49,935	2,355,992
	514191		On-line information services	Taxable	4,165	8,042,568	49,935	2,355,992
7376			Computer facilities management services	Taxable	1,445	15,114,194	71,821	3,389,511
	541513		Computer facilities management services	Taxable	1,445	15,114,194	71,821	3,389,511
7377			Computer rental & leasing	Taxable	946	5,744,535	9,112	569,196
93% of	532420	90	Computer rental & leasing	Taxable	946	5,744,535	9,112	569,196
7378			Computer maintenance & repair	Taxable	6,087	7,565,169	60,406	2,258,017
89% of	811212	30	Computer maintenance & repair	Taxable	6,087	7,565,169	60,406	2,258,017
7379			Computer related services, n.e.c.	Taxable	28,762	21,541,285	174,926	9,313,021
	334611		Software reproducing	Taxable	124	1,258,435	8,027	310,933
31% of	541512	20	Computer systems consultants (except systems integrators)	Taxable	20,233	15,942,861	129,785	7,117,694
100% of	541519	Σ	Other computer related services	Taxable	8,405	4,339,989	27,598	1,884,394

U.S. Census Bureau Information for Class 3 (Credit Institutions, Business Services, Television & Computer Services)

SIC	NAICS	Pt	Description		Establish-ments	Revenue ($1,000)	Paid employees	Annual payroll ($1,000)
	541519	10	Computer consultants (except computer systems consultants)	Taxable	7,604	3,432,145	27,598	1,559,897
	541519	90	All other computer related services	Taxable	801	907,844	9,516	324,497

D

PRELIMINARY ESTIMATE OF ELECTRICAL USAGE OF DIGITAL EQUIPMENT*

Sector*	Digital Load Type		NAICS vs. SIC	Estimated Annual Energy Use 1999 (LBNL) (TWh/yr)	Estimated Annual Energy Use 2001 (with 3% increase per year) (TWh/yr)	% of Total Electricity Use Today (Using EIA 2000 Total Usage) (%)
Residential	Portable Computer			0.14	0.15	0.00
	Desktop Computer			2.67	2.83	0.08
	Monitor			3.13	3.32	0.10
	Cable Modem				0.00	0.00
	**Home Electronics				126.57	3.71
	Printer			1.2	1.27	0.04
	Copier			1.1	1.17	0.03
	Fax Machine			0.44	0.47	0.01
Total				*8.68*	*135.77*	*3.98*
Commercial	Portable Computer			0.13	0.14	0.00
	Desktop Computer			10.21	10.83	0.32
	Server			1.6	1.70	0.05
	Minicomputer			8.86	9.40	0.28
	Mainframe			5.62	5.96	0.17
	Terminal			1.83	1.94	0.06

	Monitor			9.82	10.42	0.31
	Printer			6.92	7.34	0.22
	Copier			5.71	6.06	0.18
	Fax Machine			2.26	2.40	0.07
	Hub			0.65	0.69	0.02
	Switch			1.55	1.64	0.05
	Point of Sale Terminal			5.4	5.40	0.16
	Router			0.73	0.77	0.02
	Access Device			0.29	0.31	0.01
total				*61.58*	*65.00*	*1.91*
Industrial	Adjustable-Speed Drive				1.41	0.04
	Automation Unit (PLC, AC and DC control power, sensors, motor starters. etc. fed from a single source)				20.70	0.61
	Distributed Control System					
	Portable Computer			0.02	0.02	0.00
	Desktop Computer			1.46	1.55	0.05
	Server			0.23	0.24	0.01
	Minicomputer			2.95	3.13	0.09
	Mainframe			0.63	0.67	0.02
	Terminal			0.61	0.65	0.02
	Monitor			1.4	1.49	0.04
	Printer			0.99	1.05	0.03
	Copier			0.82	0.87	0.03

	Fax Machine			0.32	0.34	0.01
total				*9.43*	*32.11*	*0.94*
TOTAL All Sectors				79.69	232.89	6.83

*Not formatted based on Classes 1-3 as described in Chapter 2; also missing data for lighting and power conditioners.
**Home electronics numbers appear high, but confirmed by EIA data for 2001.

E
SUPPLEMENTAL MATERIAL

NAICS Industry, Product, and Service Classifications

The North American Industry Classification System (NAICS) is replacing the U.S. Standard Industrial Classification (SIC) system. NAICS will reshape the way we view our changing economy. NAICS was developed jointly by the U.S., Canada, and Mexico to provide new comparability in statistics about business activity across North America

NAICS industries are identified by a six-digit code, in contrast to the four-digit SIC code. The longer code accommodates the larger number of sectors and allows more flexibility in designating subsectors. It also provides for additional detail not necessarily appropriate for all three NAICS countries. The international NAICS agreement fixes only the first five digits of the code. The sixth digit, where used, identifies subdivisions of NAICS industries that accommodate user needs in individual countries. Thus, six-digit U.S. codes may differ from counterparts in Canada or Mexico, but at the five-digit level, they are standardized.

The NAICS, which is relatively new, will eventually develop a cross reference with the older International Electrotechnical Commission (IEC) product families. The IEC product family that best describes digital end-use equipment is *Information Technology* (IT).

Measuring electronic business is a major challenge for future statistical programs. The general class that begins to address e-business is designated as “Information,” Class 51 in the new North American Industry Classification System (NAICS). NAICS is expanding and will replace the familiar Standard Industry Codes (SIC) to include more specific product tracking. For more details, “A Bridge Between NAICS and SIC” (http://www.census.gov/epcd/ec97brdg/) provides 1997 economic census data.

ECPC Product Classification Initiative

Another development that will facilitate tracking digital energy use is forthcoming in conjunction with the changeover to NAICS. The Economic Classification and Policy Committee (ECPC) of the U.S. Office of Management and the Budget is currently developing a comprehensive classification system for the products produced by the spectrum of U.S. industries that have recently been defined and classified under NAICS.

The ECPC initiative will be implemented in two phases. Phase 1 is an interim, or exploratory, phase launched in 1999 to produce preliminary results for a subset of NAICS service industries; these results will be incorporated into the questionnaires for the 2002 Economic Census. Exploiting the lessons and insights gained from the deliberations and the data collection activities of Phase 1, a second, or final, phase of the initiative will be launched after the 2002 Economic Census to develop a complete and fully integrated product classification system that extends to all NAICS industries. The results of Phase 2 are to be incorporated into the questionnaires for the 2007 Economic Census.

The ultimate objective of the ECPC initiative is to develop a market-oriented/demand-based, classification system for products that (a) can be linked to the NAICS industry classification system but is not industry-of-origin based, (b) is consistent across the three NAICS countries, and (c) promotes improvements in the identification and classification of service products across international classification systems, such as the Central Product Classification System of the United Nations. Towards this objective, the goal of Phase 2 of the initiative will be an agreed-upon, integrated, and comprehensive list of products, product definitions, and product codes that (1) encompasses both services and goods alike and (2) accommodates a demand-side/market-oriented classification framework for grouping and aggregating these products.

In preparation for Phase 2, the goal of Phase 1 is to systematically explore the seminal development of a formal classification system for service products that can be used throughout the business and economics communities of users to coordinate the collection, tabulation, and analysis of data on the value of the detailed products produced by service industries and on the prices charged for those products.

Phase 2 will develop (1) a comprehensive list of products that encompasses both goods and services products alike and (2) a demand-side/market-orientated classification framework for grouping and aggregating these products. The products of four NAICS service sectors are being defined. Sponsors of NAICS are looking for knowledge of products in the industries of these service sectors and help to recruit experts on the industries in these sectors. Proposals are being accepted for specific areas. The Initiative will be implemented in two phases. First, an interim, or exploratory, phase will be launched in early 1999 and it is expected to produce preliminary results for a subset of NAICS service industries; these results will be incorporated into the questionnaires for the 2002 Economic Census. Second, exploiting the lessons and insights gained from the deliberations and the data collection activities of Phase 1, a second, or final, phase of the Initiative will be launched after the 2002 Economic Census to develop a complete and fully integrated product classification system that extends to all NAICS industries. The results of Phase 2 are to be incorporated into the questionnaires for the 2007 Economic Census.

This product classification system will be used to coordinate the collection, tabulation, and analysis of output and price data for products. The project is being implemented in two phases: Phase 1 (products of selected service sectors.) and Phase 2 (products of all goods and services sectors.)

Phase 1 will be an exploratory effort that focuses on the identification and classification of the products sold by service industries in four selected service sectors:

1. Information (Sector 51).
2. Finance and Insurance (Sector 52) except Insurance (Sub-sector 524).
3. Professional, Scientific, and Technical Services (Sector 54).
4. Administrative and Support, Waste Management, and Remediation Services (Sector 56).

Phase 2 will develop (1) a comprehensive list of products that encompasses both goods and services products alike and (2) a demand-side/market-orientated classification framework for grouping and aggregating these products. The products of four NAICS service sectors are being defined. Sponsors of NAICS are looking for knowledge of products in the industries of these

service sectors and help to recruit experts on the industries in these sectors. Proposals are being accepted for specific areas.

Programmable Logic Controllers

The function of early PLCs was to manipulate relays wired to its discrete inputs (See *Control Engineering*, Oct. 1995, “The Evolution of PLC-Based Loop Control,” p. 57). Thirty years later, they remain a steadfast and growing component to various industries. Customers want a simplified way to deal with large-scale issues that increasingly affect their process automation project decisions. Issues include globalization, technological change, and ever-increasing customer requirements. Manufacturers are adding more functionality to smaller and faster programmable logic controllers (PLCs) that blend and work with PC-based software.

The future of PLCs seems bright and some say the jury is still out on whether or not PC-based solutions will dominate future industrial control. "PC-based controls will play an important role until PLCs and PLC-type systems become more open, intelligent, affordable, and move away from proprietary networks. Users demand the kind of flexibility that PC-based systems launched, the ability to change software layers without changing hardware, and to use commercially available technology whenever appropriate or possible," says Benson Hougland, director of technical marketing for Opto 22 (Temecula, California). (Source: http://www.controleng.com/)

Convergence between PLCs and PCs?

The early days of PC-based control were very much an "us versus them" time. PC advocates were breaking new ground using commercial standards for industrial control. The "stodgy, proprietary" PLC companies were seen as standing in the way of true innovation and industry advancement.

But one of those "stodgy, proprietary" companies—Siemens’ Software Business Unit (Princeton, New Jersey) is coming a long way into breaking into the PC game. The emphasis on PCs comes because managers see many changes occurring today. Application code is becoming more sophisticated. Data transparency is required throughout the enterprise. Engineering is moving to concurrent team design with more C++ and computer skills, while cost of engineering, configuring, and programming has become a major cost component of an automation project.

One initiative is development of a Universal Development Environment (UDE). This is a concept that has just hit the pages of *Control Engineering* with force within the last year. Often looking like Visual Studio, these tools really help control engineers get a handle on programming projects. The Open Developers Kit uses "component" technology to enable integrated motion, vision, and user defined C/C++ algorithms into PC-based control. Expect to see more discussion of tools like these from Siemens and others in future issues of *Control Engineering.*

IT Industries’ Place in the Economy

- IT industries produce less than 10 percent of total U. S. output.
- Nevertheless, between 1995 and 1999, because of IT industries’ extraordinary growth and falling prices, they accounted for an average 30 percent of total real U.S. economic growth.
- Price declines for computers and peripheral equipment and for communications equipment have spurred major increases in business IT investment and extraordinary growth in the U.S.

- Output growth in these industries has jumped from about 12 percent a year in the early 1990s to roughly 40 percent in the past 6 years.
- In 1980, there were 2 million computers in the U.S.
- Per Financial Times, some 150 million computers will be sold in the U.S. in 2001.

This dynamic growth increased IT industries' share of total output from 6.3 percent in 1994 to an estimated 8.3 percent in 2002. By contrast, between 1990 and 1994, these same industries' share of the economy grew much more slowly—by only about 0.5 percentage points overall.[49] (Source: Digital Economy 2000, DOC). IT-producing industries count for nearly one third of real GDP growth from 1995 to 1999.

As a result, real business investment spending on IT equipment and software more than doubled between 1995 and 1999, from $243 billion to $510 billion (1996 dollars), while real spending on transportation equipment increased by about half and real spending on other capital equipment increased slightly.

Growth in IT industries' share of private R&D is largely the result of increased R&D investment by manufacturers of electronic components and software. In the computer industry, annual R&D investment dropped from an average $11 billion during 1990-92, to $5 billion during 1993-95, then rose to $10 billion during 1996-98. One reason for this lack of overall growth may be that as computer demand has shifted toward microcomputers, more computer-related R&D has shifted to component manufacturers and software firms.

Telecommunications Technology

Switches, routers, and hubs are all different yet fundamentally similar devices and are, in fact, often integrated into a single product. These components form the roots of the telecommunications architecture for the digital society and within IDCs and provide the gateway through which all data entering or leaving must pass.

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[49] IT-producing industries' share of the economy is calculated from its Gross Product Originating (GPO) as a percent of the economy, as measured by Gross Domestic Income (GDI). Theoretically, the nominal dollar value of GDI, the income associated with the output of all industries, should equal that of Gross Domestic Product (GDP); i.e., final demand or the market value of the goods and services produced by labor and property in the United States. In practice, growth in GDI and GDP has differed by half a percent in recent years.

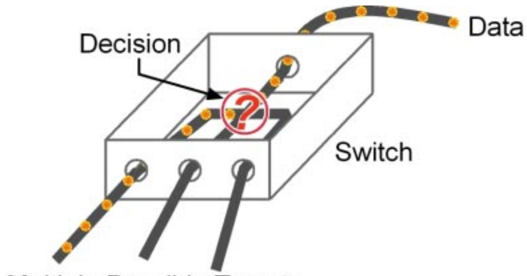

Figure E-1
Simplified Switch

Switches are network devices that choose which path or circuit a packet of data will take to its next destination. This is usually accomplished by using the IP address attached to each packet of data. This address gives the specific machine to which the data needs to be sent, though the switch only pays attention to the general direction in which the data must be moved to get to its final destination.

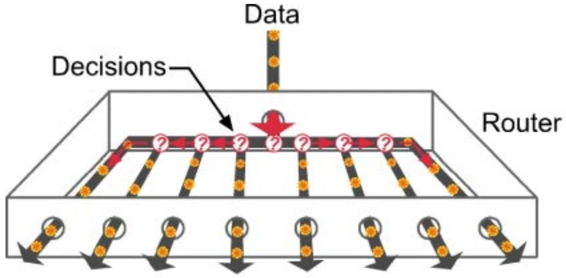

Figure E-2
Simplified Router

Routers are more intelligent than switches and determine the exact next point within a network to which a packet should be forwarded to get to its destination. The router makes intelligent decisions based on the information it possesses about the connected networks and sends the data along the most efficient path from its analysis. The degree to which the routers do this kind of network management depends on how sophisticated they are. Routers are also present at any point where two networks meet, a point called a gateway.

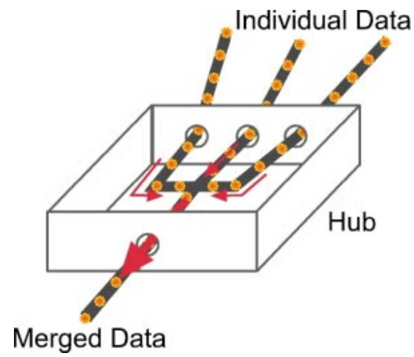

Figure E-3
Simplified Hub

A hub is a device in which data comes together from multiple sources, like the hub of a wheel is where the spokes join. Hubs can include switches and routers, and switches and routers are usually also hubs or are attached to hubs.

Some popular manufacturers of these types of equipment are: Cisco, Intel, 3Com, U.S. Robotics, Nortel Networks, Alcatel (no longer part of Lucent Technologies), Rapid Stream, Secure Works, Riverstone Networks, and Entrasys Networks.

Servers: A Basic Definition

A server is, in the strictest sense, a piece of software designed to handle requests from an outside party. In the hardware world, the word server can be used to refer to any system with a CPU that runs one or more server programs. These devices are usually made of higher quality components than regular personal computers in order to provide for a higher rate of availability since the non-stop role of these components requires them to function in a 24/7/365 manner with minimal downtime.

There are several kinds of servers, many that have little technological differences, but it is important to understand the distinctions between them in order to be able to assess various trends. The following is the primary list of server types:

- Web Servers
- Application Servers
- Wireless Servers
- Proxy and Firewall Servers
- E-mail and Messaging Servers
- File Transfer Protocol (FTP) Servers
- Appliance Servers

Web servers are the most basic type of server in today's market. Their function is simple, to receive requests by a client (i.e., a web browser), and send the requested file to the client. The wireless and application servers are natural outgrowths of the basic web server. The differences being that the wireless server is able to transmit files in a format readable by wireless technologies, such as WML, and the application server is able to interact with a client in a much more complex manner by doing calculations and running other processes before delivering the requested content.

Proxy servers are usually found in intranets where they serve as the gateway between the intranet and the Internet, allowing the network greater control over traffic. Firewalls are used to build a "wall" between networks, providing security and monitoring traffic. E-mail servers, obviously, handle functions such as e-mail. File Transfer Protocol (FTP) servers are used to transfer files from the server to another machine and vice versa.

The other type of server listed here, the appliance server, is not really a distinct type of server at all. Instead, an appliance server is another type of server that has been configured in such a way that it would be a small matter to plug it into an existing network. Thus, an "application appliance server" would be an appliance server that is as close to "plug and play" as possible while a "web appliance server" would be a web server with about the same level of network readiness.

Table E-1
Rack-Mounted Server Electrical Consumption Trends

Company	Product	Depth (in rack mount)	Power (watts)
Sun	Netra X1	13"	83
Dell	Power Edge 350	22"	126
Compaq	Prollant DL 320	22"	180
IBM	X series 330	25.7"	200

Source: *Financial Times News*, April 23, 2001

Servers shouldn't demand a lot of personal space. – *Financial Times News*, April 23, 2001

Lighting

Lighting has a considerable impact on U.S. energy use and on the environment. It is one of the major energy end uses in buildings and exterior applications, and the electricity needed for lighting consumes fossil fuels, which contribute to air and water pollution. In addition, some lighting equipment is fairly short-lived and creates a continuous waste stream that may require special disposal policies.

Based on these impacts, the development of more efficacious light sources is of primary importance, both in the wise use of energy and in improved environmental protection. Currently, buildings consume over one-third of all sources of energy used in the United States and electricity accounts for almost 80% of the cost of that building energy consumption. Overall, lighting is estimated to account for 23% of national electricity consumption. Of national lighting energy use, residential lighting is estimated to constitute about 20%; commercial lighting, 60%;

industrial lighting, 16%; and other uses, 4%. The commercial lighting segment was estimated to consume 4 quads (365 billion kWh) of energy in 1997.

Of the common lamp types, incandescent lamps represent the major type used in residential lighting. Commercial lighting includes both tubular fluorescent and high-intensity-discharge (HID) lamps; the split is approximately 2/3 fluorescent to 1/3 HID. Industrial lighting includes both fluorescent and HID, while street lighting is largely HID.

We have reached a plateau in discharge (fluorescent) lamp efficacy over the last several years. The major development in lighting recently has been in the area of light-emitting diode (LED) lamps, which have a relatively low efficacy but reported lamp life of up to 100,000 hours. Work in this area, for both LED and organic LED (OLED) lamps, is being vigorously conducted by the major lamp companies.

The area EPRI has chosen for its research program, and which is being actively pursued, is to improve the understanding of fluorescent and HID lamps and to achieve breakthroughs in these technologies that will result in greatly improved efficacies. The short-term goal for the ALITE II program is to develop a commercial lamp with efficacy greater than 150 lumens/watt within five years. The long-term goal is to improve the efficacy for these lamps to over 200 lumens/watt.

To meet the goals described above, EPRI has formed three multi-disciplinary teams in three separate areas:

Improved fluorescent (discharge) lamps (a part of ALITE II) - The team consists of EPRI, NIST, Los Alamos National Laboratory, University of Illinois, and the three major lamp companies (General Electric, Osram Sylvania, and Philips Lighting). This work is funded by EPRI and the three lamp companies and builds on the work conducted in the ALITE I program. In that program, jointly funded by EPRI and Osram Sylvania, a greatly improved understanding of mercury-rare gas discharges was obtained, resulting in improvements in Osram's current line of fluorescent lamps. In addition, a new atomic radiator, barium, was studied as a possible replacement for mercury-based discharge (fluorescent) lamps. The current work under ALITE II will investigate molecular discharges as sources for advanced lighting systems.

Multi-photon Phosphor Systems – This team includes EPRI, Osram Sylvania, and selected consultants, under the sponsorship of the U.S. Department of Energy. The program seeks to determine the feasibility of developing a phosphor material that emits two or more photons for every electron collision, thus doubling (or more) the lamp's efficacy. When preliminary findings are reviewed in 2002, a determination will be made on whether to seek follow-on funding for laboratory development work.

Improved High-Intensity Discharge (HID) Lamps – The team consists of EPRI, NIST, Los Alamos National Laboratory, University of Wisconsin, and GE, Osram Sylvania, and Philips. In typical HID lamps, 90% of the electrical power goes to the lamp's arc column and 10% goes into electrode losses. Eventually, only 33% of the total power in the column is converted into visible light, with 57% of the deposited power in the arc column escaping through non-useful channels. The goal of this work is to seek ways to limit the power lost in unwanted channels and transform it to visible light. It is anticipated that the efficacy of HID lamps could be increased to 150 lumens/watt.